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PHOTO BY WRIGHT & COOK, PHILADELPHIA

James M. Dodge

PRESIDENT OF THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS

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CASSIER'S MAGAZINE

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COINING MACHINERY IN CHINESE MINTS

By Oberlin Smith and Henry A. Janvier

SEVERAL years ago it fell to the lot of the writer first mentioned above to design some machinery for producing certain coinage issues for the Chinese Government. One of the plants in question was to be located in the city of Wuchang, capital of the province of Hoo-Pe, and was to be used exclusively for making the small brass coins with a square hole in the middle, popularly known as "cash," or, as they are called in China, "tsen." The machines for this particular mint were to produce something over 300,000 pieces per day, the design of these coins being shown, in obverse and reverse, on page 5.

Another plant was to be located in the city of Chentu, in the province of Szechuen, which a reference to a map of China will show to be in the central western portion of the Empire. The coins made therein were brass "cash," of the same weight as those made in Wuchang, but of a somewhat larger diameter, and a slightly different design. The production in this mint was required to be at the rate of something over 250,000 coins per day.

The third plant was also for the province of Szechuen, and was exclusively for the production of silver coinage of the denominations, respectively, of 5 cents, 10 cents, 20 cents, 50 cents and $1, as shown grouped in pairs in the illustration at the top of the next page, each coin appearing in obverse and reverse. The total capacity required for silver pieces, in the aggregate, was about 150,000 per day.

An inspection of these silver coins will show a very beautiful design, the purely Chinese inscriptions on the reverse being, of course, more graceful than legible to the ordinary reader. On the obverse the horrible dragon has not only an expressive countenance, but an exceedingly graceful pose. The inscription surrounding him is simply a literal translation of the outside, similarly placed, inscription on the reverse side. The central inscription on the reverse relates to the name of the Emperor and dynasty, and is in ordinary Chinese characters, except the very small central portion, which is Manchurian. It will be noticed that the design and inscription on all five sizes of the coins are identical, except that portion below the dragon (and its translation on the other side), which relates to the denomination of each individual piece.

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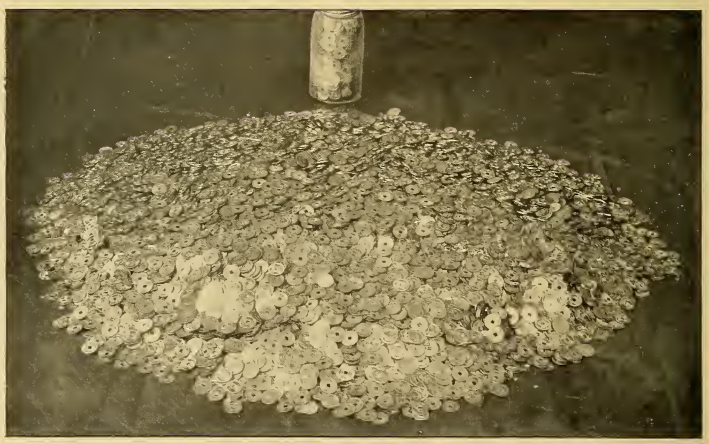
CHINESE SILVER COINS



A HEAP OF MISCELLANEOUS COINS. TEST PIECES FROM NEW COINING MACHINERY

In making a study of these coins, entirely outside of mechanical and artistic points of view, we may trace some curious facts which point to the general feeling of the Chinese regarding America, and to their ideas, probably entirely unformulated, regarding future political and commercial relations with that country. Not only were these coins freely spoken of in correspondence as dollars and fractions thereof, but the weight of the silver dollar was made exactly the same as that of the American standard dollar, viz., 412½ grains. The composition of its alloy was also made the same, being what is technically known as nine-tenths fine,—that is, nine of silver to one of copper. Furthermore, the inscriptions were all put in English upon the obverse of the coin, in close communion with the holy dragon. Do not such significant facts afford a peep between the portals of the "open door" and indications that this opening is to

be a wide and ever widening one? The fixing of the weight and the consequent value of the coins in question is still more remarkable as being in disagreement with the Chinese decimal system, in which 10 tsen make one candareen, 10 candareens one mace, and 10 mace one tael,—the tael, as is well known, being a national standard of value throughout China. It is, however, a certain weight of silver merely, and not a coin.

It will be noticed from the coins that in breaking up, so to speak, their decimal system, its remnants were used for stating the value of the silver pieces in the inscriptions upon the new coinage. Thus, the value of the dollar is made to read 7 mace and 2 candareens; the 20-cent piece, 1 mace and 4.4 candareens; the 5-cent piece, 3.6 candareens, and so on.

An interesting fact in connection with the minor coins belonging to the series in question is that the half-dollar is exactly half of the dollar, and the dime exactly one-tenth of the dollar, with the others in like proportion. Whether this arrangement is due to native honesty or

"CASH"

what not, it is in marked contrast to the American plan, where the so-called aliquot parts of the dollar are depreciated to a somewhat less value than their name would imply.

In the lower illustration on the opposite page is shown a heap of miscellaneous coins photographed from a pile as it lay on a table, after having been run through the new machinery in the shops where it was made. These coins were merely test pieces produced in a trial run, and were, of course, carefully melted down afterwards.

In many parts of China it is still the custom to use silver bullion for values which cannot be conveniently paid in

THE MINT OFFICIALS

CHINESE HOUSE-BOATS FOR RIVER TRAFFIC

cash. A friend of the writers, who has lived for about thirty years in a northern province not very far from Peking, is still obliged to take bars of silver to his tradesmen for making ordinary purchases, having them cut by his blacksmith to as near the size as he can guess for the particular purchase in question. The plus or minus amount, due to imperfect guessing, is made good by "cash," either to or by the purchaser, as the case may be. Financial difficulties similar to the above mentioned were more than once experienced by the members of our party during their journey.

Another instance of the inconvenience of the Chinese style of "cash" payments may be cited in regard to certain gentlemen who, having sold about $30,000 worth of goods, received their payment in these interesting little coins. The result was several days' work with horses and carts to get the money to a bank, where it could be changed into silver. The coining machines under consideration, together with various driving and transmitting machinery, as boiler, engines, and shafting, were duly shipped to China, followed after a proper interval by Mr. Janvier in person, who, while acting in the rôle of money furnisher to whole provinces of a great empire, might fitly be termed the consulting financier of the expedition. As, however, he had not become a proficient conversationalist in the various languages of China, and was going into a part of the country unpeopled by, and almost unknown to, English-speaking persons, he was duly joined in Shanghai by an interpreter.

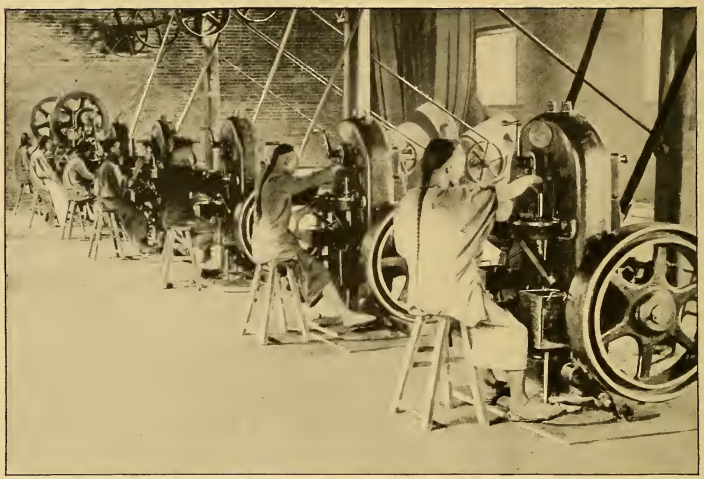
The first part of the journey of the voyagers was made in a comfortable steamboat up the Yang-tse-Kiang as far as Wuchang, where the first consignment of machinery was to be set up. The country along this portion of the river is mostly devoted to farming and fishing, the land lying low and flat and the scenery being monotonous. The city of Wuchang has a population of

about 800,000, and is the seat of the provisional government of Hoo-Pe. Besides the government buildings it contains an agricultural college and an arsenal, in which latter building the coining machinery was to be erected. Here it was found that the Chinese engineers and mechanics had unpacked and put up the machinery in a perfectly proper way, although they had never seen anything of the kind before. Their only guide to this work was a somewhat elaborate written list of directions, accompanied by photographs of the machines, both complete and in parts. These directions they evidently must have had translated, so as to enable them to work from them. As, however, the power supply was not ready, the running of this machinery was deferred until the return trip of the party.

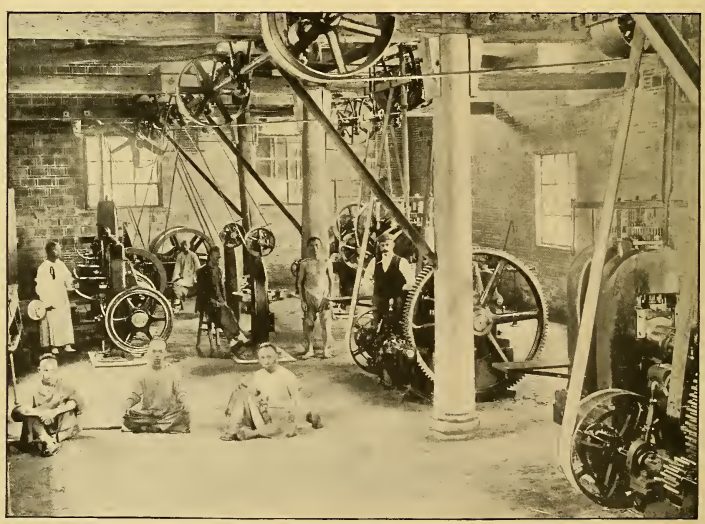
The city of Hankow, on the north side of the river opposite Wuchang, is a very wideawake town, having many cotton factories and machinery supply stores. After a day or two of waiting, the voyage up the river was resumed in a much smaller steamboat, which was by no means so comfortable as the other. Through this part of the country the natives began to show some of their traditional jealousy and dislike of foreigners, manifesting them on several occasions when the boat stopped at a wharf by throwing sticks and mud at the passengers, sometimes even hurling stones of considerable size. Their conversation, to say the least, was of a lively character, the subject of it seeming largely to be connected in some way with "pigs" and "foreign devils." It is a frequent occurrence for passengers to amuse themselves by returning these attacks with stones which are provided in buckets by the steamer management. After an interval of seven days the head of steam navigation was reached at Ichang, which is between 700 and 800 miles from Shanghai, by the course of the river. At this place, which has something over 30,000 inhabitants, a decidedly ugly spirit toward foreigners is usually manifested by a considerable part of the population. The foreign devils, however, did not appear to care much for this, and, under the moral protection of the British and American consuls, seemed to enjoy frequent excursions back from the river, where they got beyond any actual protection, even going so far as to play golf in the country north of the town without any special molestation.

For the resumption of the voyage a change of boats was made at Ichang, an ordinary houseboat, so-called, being substituted for the steamer. This was a craft about 35 feet long by 8 feet wide, with a flat bottom and scow-like ends, numerous boats of this kind being seen upon the river at all times. It was pro-

THE PILOT AND CAPTAIN OF ONE OF THE HOUSE-BOATS



"CASH" COINING ROOM IN ONE OF THE MINTS



A SILVER COINING ROOM

vided with a captain, a cook, and a crew of twelve men, being in this case a yacht especially provided by the government for the party, who were provided with servants in addition to the regular boat's crew.

The propulsion of this sort of craft is by sails whenever there happens to be a fair wind, but otherwise by poling, rowing, or towing. The crew, when the latter method is used, take the part of the tow-path mule, the tow-path itself in many cases being merely the very rough river banks in their natural condition.

The monotony of this section of the voyage was varied by a couple of shipwrecks. The first one was caused by striking on a sunken rock, which punched a hole through a planking as big as a dinner-plate, more or less. The boat and its occupants were saved, however, by a brave Chinaman, who sat in the hole, with rare presence of body, until the craft could be gotten ashore for repairs. On the other occasion the towing rope broke, and the boat was hurled in an unmanageable condition for a mile or two down a rapid-infested part of the river, finally running aground, but without any very great damage.

Numerous accidents of this kind occur in navigating this somewhat treacherous stream, and many natives are drowned. None of the boats attempt to navigate at night, on account of the dangers incurred; every evening as darkness approaches whole fleets may be seen tied up along the banks.

The menu usually served to cabin passengers during a voyage of this kind is, for breakfast, rice and beans; for dinner, rice, beans and rice; for supper, beans and rice. This bill of fare was occasionally enriched by small fish, caught from the river. Our party, however, fared sumptuously every day on European food brought with them from Shanghai. The usual beverages among the poor of China are rice-water and tea, all natural water being unfit to drink.

After a trip of twenty days, nearly due west from Ichang, the town of Wan was reached, and there a convoy, furnished by the government, was awaiting our party for a march overland of about 400 miles to the city of Chentu, the rivers Yangste and Min, which connect the two places by water, making a long detour to the southward. This would require a voyage of a great many days, and, therefore, the overland route is usually chosen for the up-trip, although in returning eastward the river route is the quickest, on account of the rapid current.

The convoy in question consisted of soldiers, sedan-chairs, bearers, baggage carriers, cook, and other servants. The trip was in many places through a beautiful country, sometimes over high hills, but more often over roughly-made roads, following the valleys, and winding in devious ways between rice fields in all stages of cultivation.

A noticeable feature of Chinese agriculture is the immense amount of trouble taken by individual small farmers to use every square foot of ground that is possibly available, thus showing the overcrowded condition of the country. The poverty of many of the natives is indeed pitiful to see, their chief and urgent needs being sufficient rice to keep them barely alive, together with such clothing as will keep them partly warm. Their houses are usually made of bamboo and mud, with an occasional 10 by 20-foot mansion having walls of the same materials, but enjoying the distinction of a tile roof.

The warming of these houses is accomplished by lighting an open fire of grass and sticks on the middle of the dirt floor. There is no chimney. Such illumination as their denizens occasionally indulge in is attained by the use of paper lanterns equipped with very poor candles, or by a primitive lamp made of an iron dish of grease with a stick for a wick. A strikingly noticeable feature of the topography of this part of the country is its extreme hilliness, a large proportion of the whole surface being unfit for tilling, even by the very industrious and economical toilers who utilise all the land available.

In passing through villages frequent

A CHINESE IDEA OF RAPID TRANSIT

opposition and abuse were encountered, it being on more than one occasion necessary to draw pistols for threatened defence against the small mobs with their noisy, but bloodless assaults. Fortunately, however, nobody was hurt. The most amusing part of the proceeding of driving off the mob was usually the disappearance of the soldiers, who hid themselves until the trouble was over. Had much fighting been necessary, however, the weapons carried by this guard, consisting of bamboo sticks, would not have been very deadly in effect.

The various village inns where the nights were spent were fairly comfortable, the food served consisting chiefly of rice, with beans, cabbages, and carrots for entrées,—and a possibility of eggs and chickens for festive occasions. It was, however, difficult to secure that degree of privacy in the guest chambers of these hostelries which is conducive to sound and healthy slumber, the natives attempting to inspect and purloin any loose articles left around the room by the sleepers at any and every hour of the night. The overland pilgrimage extended over about fourteen days, terminating at the city of Chentu, the capital of Szechuen, which is the largest province in China, with a population approximating 68,000,000. This city, by the route taken, is about 2,000 miles from Shanghai. Here it was found that in all this great city of 700,000 population there were no English-speaking people, except a few missionaries, who were scattered through various quarters of the town. In commercial or official life, however, nobody could be found who spoke other than Chinese. Such western civilisation as up to this time exists in Western China is due largely to the faithful work of the missionaries, who bravely stand their ground against many difficulties and dangers. Too much cannot be said of the kindness of the Chentu missionary colony to our little party, who were cheered and comforted throughout their sojourn by continued courtesy and hospitality.

Our party of travellers were promptly met by the officials of the government arsenal, who were extremely polite and friendly, and whose words of welcome were understood through the good of-

fices of the interpreter. The same jealous care, or attempted care, that had been taken of these envoys by the government authorities was here continued, quarters being assigned them inside the arsenal walls,—not only that they might be available for the official business on hand, but that their lives might be protected against mobs or any other possible dangers existing in the town outside.

It was now discovered that all of the numerous cases of machinery had not arrived, although they had been many months in transit. The missing ones were soon found to be stranded a short distance down the river Min, which runs through the city at this point. The excuse for not bringing them up to the arsenal was "low water" and "high water," the boats being just then stuck in the mud for want of water, and having been unable to get up the stream when the water was high because they could not pass under a certain bridge. This trouble was soon remedied, by having a dam built, which raised the lower end of the stream without letting the water approach too near the bridge at the upper end, much to the joy of the Chinese observers. This scheme was perfectly feasible by reason of a considerable fall between the two points.

When the unpacking process commenced it was found that on certain of the machines the strongly and carefully made boxes had been entirely removed somewhere en route. It was afterwards discovered that this wood had been taken off by some Chinaman who wanted to use it for patching up his house. As it afterwards proved, he had been caught, severely whipped, and tied up for two weeks with a large board around his neck. A majority of the boxes, however, appeared intact; but when they were opened it was found that some of the delicate machinery was imbedded in fine dried mud, which had silted in through small cracks.

PLOUGHING IN A RICE POND

Another portion of the contents of

these boxes which, beside the mud, was foreign to the cognizance of the American packers, were various colonies of rats, which, it seemed, had eaten their way through the wood and made nests among the straw, paper, and mud surrounding the machinery. Further inquiry as to the source of this mud elicited the fact that the machinery had been transferred from the steamer at Ichang to the sloping bank of the river. The intention was to ship it upon a house-boat within a day or two; but one of the numerous floods to which the Yang-tse is liable happened to arrive inopportunely, with the consequence that the cases were left submerged in a muddy current for about six weeks.

This submergence was not calculated to improve the accurate work of iron and steel, which was thoroughly coated with rust, in spite of its thick coating of grease, thus necessitating the entire taking apart and repolishing of many pieces which had been assembled and supposed to be ready for operating. One great difficulty in this case was to convince the Chinese officials (some of them excellent mechanics) that the machinery was new, some of it, indeed, being condemned at first as old junk.

Everything, however, was finally restored to fairly good condition, except the finely engraved coining dies. Some of these were apparently ruined, numerous blotches appearing in the dragons and other parts of the design. However, the damaged parts were tried in the coining presses for the sake of showing the officials their general operation, with the most agreeable disappointment to find that the Chinese were highly pleased with the accidentally altered designs, thinking them much superior to the original, on account of the difficulty that counterfeiters would have in imitating them. Everybody, therefore, was happy, and both the plants were started up, to the entire satisfaction of the Chinese authorities in charge.

In this city it was rather surprising to find a fairly well-equipped arsenal, with its accompanying machine shops and foundries, everything being run by native Chinamen, although some of the machinery had been made in England. When the new engine for the coining work was set up, it was started with dozens of admiring onlookers. When its speed reached about 100 revolutions per minute they began to stare; as it went on to 150 many of them decamped in mortal fear; and as it got up above 200 the room was vacated, and the astonishment of those who afterwards ventured to return to see the machine running at nearly 300 was something rather amusing.

A remarkable episode in foundry work was to see a live chicken brought out and invoked for good luck at the beginning of the melt, being afterwards cut in half, with further invocations to its departing spirit that the melt might be hot and might run well into the moulds. Its favourable influence was then augmented by smearing the blood and feathers over the trough through which the iron was to run. The castings afterwards made were fairly good, but nothing would convince the foundrymen that they could have been made without the chicken.

The workmen who assisted in erecting the new machinery were tractable and tolerably intelligent, that is, upon days which they considered lucky; but when they elected to call a day, or days, unlucky, nothing could make them start to work. Nearly all the operations in hand had to stop meanwhile.

A curious condition of the civilisation of Chentu was forcibly brought to notice when it was found that in the whole city there was absolutely no paint, sorely as it was needed for repainting the mud-damaged machinery; nor were there any materials with which to make paint. The only pigment that could be discovered was pig's blood, which is used freely, both for textile fabrics and woodwork. Another lack was kerosene oil, or, in fact, oil of any kind, the city being lighted by a very poor quality of candles. What little kerosene there was, was considered very precious, and was kept at the arsenal for the cleaning of machinery.

After everything was successfully set up and started running, a number of

Chinamen were taught the various operations of working the silver, they having known nothing whatever of the subject previously. This consisted in melting and mixing the proper alloy, pouring into ingot moulds, rolling the ingots out in thin strips with various annealings of the metal between operations, cutting from the strips round, flat blanks, pickling and cleaning these blanks, milling the blanks into planchets, which operation consists of thickening up and rounding the edges in a special machine, and finally running these planchets through the coining presses to make of them completed coins. All this teaching was done in a few weeks.

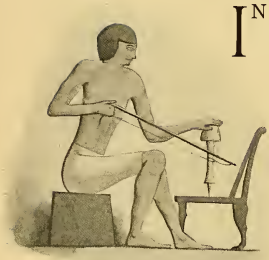
The return voyage was made entirely by house-boat, propulsion being considerably aided by drifting with the current. The course was southward and somewhat eastward by the river Min until its confluence with the Yang-tse at Szechuen was made. Thence the boat proceeded down the Yang-tse. During this voyage two more shipwrecks occurred, caused by dashing against rocks and by meeting great waves due to floods in tributary rivers. The voyage was continued past Wan to Ichang, whence a reversal of the former journey took place by a small steamer to Wuchang, and afterwards a large one to Shanghai.

Another evidence of the mechanical ability of the Chinese was shown when the mint at Wuchang was inspected. The party intended to stay there a few weeks to finish erecting and to operate the machinery, together with the giving of proper instructions to the native workmen. It was found, however, that not only had the Wuchang engineers started up the machines and made good work with them, but they had made up their minds to make the coins smaller, owing to the rise in price of copper, which took place at about that time. They had, therefore, refitted the machines with new sets of new dies, not only for coining, but for punching square holes. These they were running successfully, refusing to receive any assistance or instruction.

MODERN AMERICAN MACHINE TOOLS

FROM THE STANDPOINT OF A DESIGNER

By Charles H. Benjamin



IN choosing this title the idea has been to indicate the machine - tool problem as it appears to an outsider interested in both the ethics and the economics of design. By ethics is meant the artistic or architectural side of the problem; by economics, its practical or utilitarian side.

It will, doubtless, be said that the latter is the all-important consideration, and that it has determined, and will determine, the trend of design. True, but in machine design, as in architecture, "handsome is as handsome does," and the machine that is so constructed as to do its work with the greatest ease will ordinarily look the best.

The object of a machine tool, its *raison d'être*, is the removal of superfluous metal from castings and forgings, and the machine which does this to the best advantage is the best of its class. Several considerations must influence one in deciding just what "to the best advantage" means in this connection. The factors in the problem which have the most value are,—the time of the operator; the time of the machine; the cost of the machine; the space occupied by the machine; and the accuracy of the

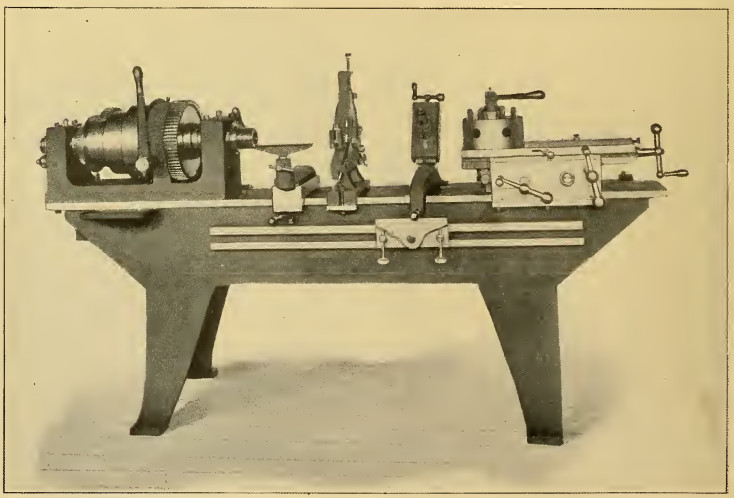


FIG. I.—A MODERN TURRET LATHE. MADE BY MESSRS. BARDONS & OLIVER, ST. LOUIS, MO.

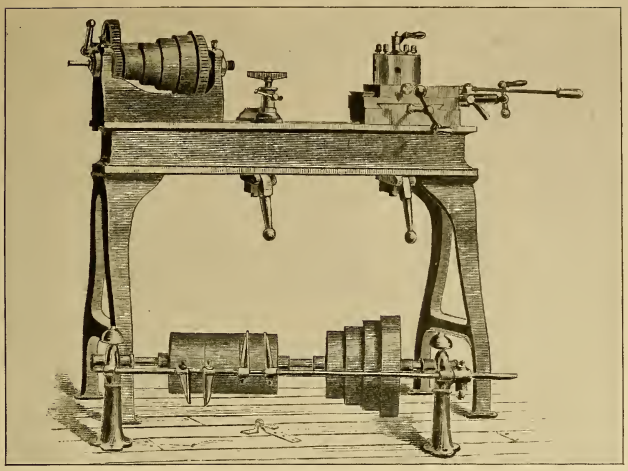


FIG. 2.—A TURRET LATHE OF 1882

work done. In other words, the best machine is that which will remove a given amount of metal in the least time, with the greatest accuracy, and with the least expense for interest, rental, and repairs. Undoubtedly the time factor is the most important, with accuracy a close second.

One must, then, look for the following characteristics as a basis for calculation:—

1. Capacity.
2. Strength.
3. Convenience.

} As determining the time factor.

4. Compactness.
5. Cheapness.
6. Durability.

} As determining the factors of interest and repairs.

7. Stiffness.
8. Good workmanship.

} As determining the factor of accuracy.

1.—A comparison of the machine tools in use to-day with those of forty, or even of twenty, years ago, will show as the most conspicuous features of development an increase in power and in capacity for doing work. This is true of all classes of tools,—lathes, planers, drill-presses and milling machines. The lathe or planer of to-day will do more work per square foot of floor space occupied than any of its predecessors,—in many instances a hundred per cent. more.

One of the severest criticisms of American machinery made by British engineers and those of Continental Europe in the period immediately succeeding the American Civil War forty years ago was to the effect that the machines, although ingenious and convenient, lacked power and strength. In their haste to produce a larger machine with the least expenditure of time and the fewest patterns, tool-builders were in the habit of "raising" a 14-inch lathe to a 16-inch one by the simple expedient of increasing the heights of head-stock, tail-stock, and tool-post without changing the other parts.

In a similar manner a 24-inch planer was stretched to a 30-inch tool by setting the housings further apart. This mechanical fraud had its counterpart in the conversion of a 200 H. P. simple engine into a 250 H. P. tandem compound by the addition of a high-pressure cylinder. To-day the reverse is the case, and, as a well-known builder recently remarked to the writer,—

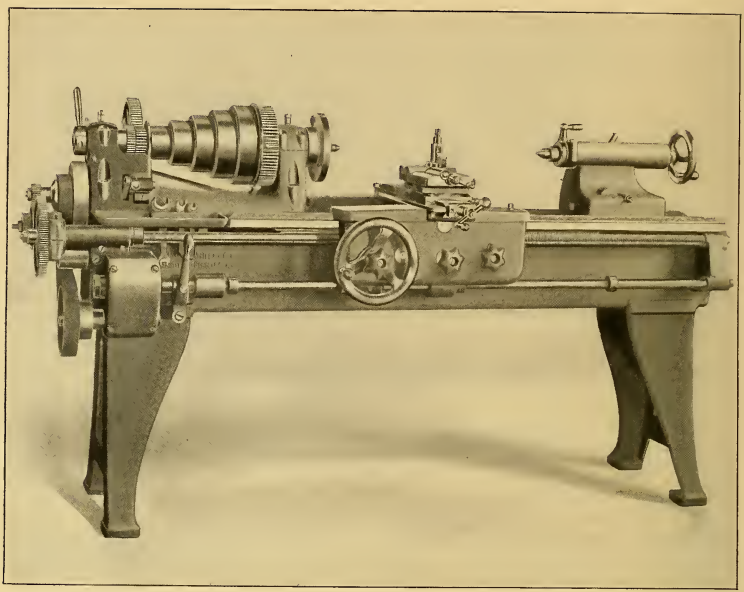


FIG. 3.—A MODERN 14-INCH LATHE. MADE BY THE PRATT & WHITNEY CO., HARTFORD, CONN.

"When a manufacturer advertises an extra heavy 14-inch lathe he means one cut down from his 16-inch patterns."

Closer competition among manufacturers who use machine tools and the consequent straining for increase of output have created a demand for more compact and powerful tools. This has resulted in the use of larger spindles, wider belts, and stronger frames.

Two factors are largely responsible for the increase of power,—the use of wide forming tools and gang cutters on small work, and the quite general adoption of air-hardening steel for single tools. The copious use of lubricants for cutting tools, such as to flood the work continuously with oil or water, is another important change.

The turret lathe illustrated in Fig. 1 has a power and a capacity for turning out work immeasurably greater than that of the machine of 1882, shown in Fig. 2. The one is simple, solid, and compact; the other, slender and sprawling.

The engine lathe, Fig. 3, has a belt power and a rigidity of frame compatible with the heavy cut and strenuous feed of the modern lathe tool. Its predecessor, Fig. 4, made by the same firm, carried a tool of ordinary steel, with a moderate cut and a fine feed. Neither the tool nor the machine would have been capable of doing what is expected of such a machine to-day.

The same comparison may be made between the modern planer, Fig. 5, and its ancestor of forty years ago, Fig. 6. The older machine, with its sprawling legs, slender bed, and delicately curved uprights, is in marked contrast to the sturdy, massive planer of the twentieth century, with every pound of metal where it is needed and all the stresses provided for.

2. Strength has, of necessity, increased with capacity, and the designs of the later machine tools show that the proper distribution of metal is receiving more careful consideration than form-

erly. Ornaments and useless curves and mouldings have been discarded, while the housings of planers and boring mills, the beds of lathes, and the arms of radial drills are examples of strength secured by proper shape.

Steel in its various forms, either cast or wrought, is an element of strength which is becoming yearly more important.

3. —As has been said above, American tools have always been noted for ingenuity of construction and convenience of manipulation. Nevertheless, the older machines had many faults from this point of view. On most lathes the back gears were not only inconvenient in changing, but dangerous as well, while the methods of changing the feed, either for turning or screw-cutting, were wasteful of time. Similar criticisms might be made in connection with planers and drill presses.

In most modern machines a distinct effort has been made to have each adjustment within easy reach of the operator, and those most frequently used so means that the changes of speed, feed, and depth of cut which are necessary for good economy will be made at the proper time, and not neglected, as formerly. Electric speed control has, in this respect, an advantage which must not be overlooked, especially on large machines.

4.—Compactness and convenience usually go together, but the former has a value of its own. Especially in city shops floor space has a considerable value, the room occupied by the machine being nearly as valuable as the machine itself.

One-story shop construction, just now so popular, has also put a premium on floor space. This is one explanation of the tendency towards vertical types of machines, such as boring mills and shapers, as taking up less room than their horizontal relatives.

5.—Cheapness in machine tools should be a result of improved design and more economical processes of manufacture, and should come also from correct arrangement of material and an

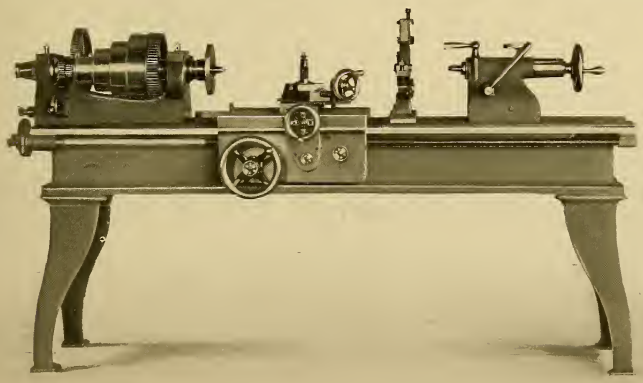


FIG. 4.—A 16-INCH LATHE OF 1881 ALSO MADE BY THE PRATT & WHITNEY CO.

located that the attendant can reach them without stirring from his tracks. Back gears have frequently become front gears, and the feed gears are changed at the touch of a lever. This entire absence of unnecessary finish. In this sense cheapness is a merit and means a better machine for the money, and not less money for a poor machine.

6.—Durability follows closely on low

first cost as a means of reducing the fixed charges in the shop. It is a prominent characteristic of modern tools, and means, in brief, larger bearing surfaces. Take the engine lathe as one example, and compare the length and diameter of spindle bearings with those in vogue twenty-five years ago. Contrast the broad, sloping *V*'s on the bed with the narrow, vertical projections which served the purpose on the lathes of 1860.

The one weak point in most modern machines of this class is in the gearing. The factor of safety usually allowed on the back, feed, and change gears is not large enough. The belt should slip before the gears break, and the writer has proved that this is frequently not the case.

7.—Stiffness in the frame and the working parts of machine tools is a prime condition, if accuracy is sought. Figs. 1 to 6 as illustrating this. The great increase in the depth and weight of bed in the modern lathe and planer is a guarantee of greater accuracy in the product. The uprights and the cross-rail of the planer, the spindles and the carriage of the lathe are all calculated to maintain their shapes under the exacting conditions of modern high-pressure service.

8.—Weight and distribution of metal alone cannot insure an accurate machine. Unless the bearings are straight and true when they leave the factory, they will always reproduce in kind. Heredity in machine work is absolute and unquestionable. Be there ever so small a kink in the spindle of the lathe, ever so slight a sag in its bed, or error in its lead screw, you may be sure that that kink, sag, and error will all reappear in its progeny. This is predestination in its

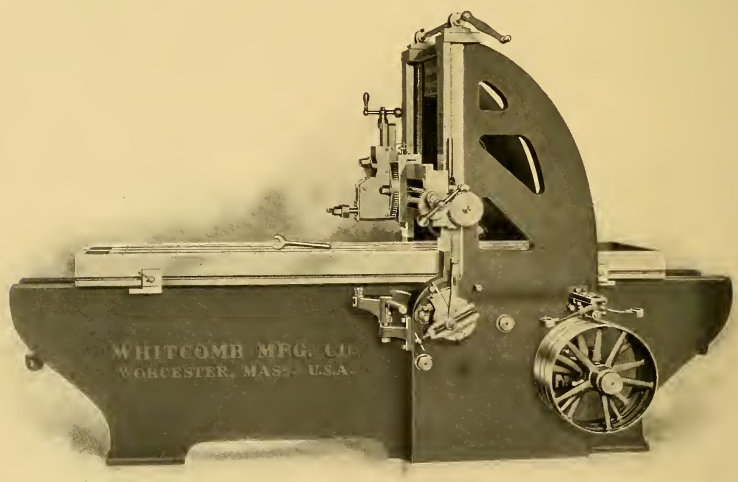


FIG. 5.—A TYPICAL MODERN PLANER. MADE BY THE WHITCOMB MFG. CO., WORCESTER, MASS.

Furthermore, a part may have ample strength and yet be so deficient in stiffness as to cause chattering and uneven work. This is particularly true of the beds and frameworks of the various machines. Attention is again called to sternest form, and the only salvation has been through the intervention of the file and the scraping tool.

There can be no question, however, as to the gradual improvement in accuracy. The refinements of modern

FIG. 6.—ITS ANCESTOR OF FORTY YEARS AGO

measuring call for a degree of precision which would have been unattainable half a century ago. Interchangeability of parts in manufactured machines and the more general use of limit gauges set a high standard of excellence for workmanship.

A modern machine tool must not only take heavier cuts on roughing work, and more of them, but in finishing it must cut closer and straighter than its ancestor of the past century. A prominent builder of machine tools, when asked by the writer to name the prevailing characteristics of modern machine design, replied,—"The absence of unnecessary finish and the increase in the area of bearing surfaces."

A glance at some of the illustrations in the present article will substantiate this. Fig. 9 represents a particularly good example of modern finish. There are no useless curves or warped surfaces; mouldings and ornaments of all sorts are avoided; corners are neatly rounded, and no machine finish is allowed, except on bearing surfaces. In the words of the builder above quoted: —"We make the foundryman do most of the work nowadays."

Figs. 1 and 3 show the same characteristics. Notice the entire absence of mouldings, the plain, flat surfaces, the disappearance of polished metal from apron, head-stock, and tail-stock, and the quiet drab of the whole as contrasted with the colour and glitter of the earlier machines.

The change from narrow to wide *V*'s has already been noticed. There is also a tendency in most machines to revert to the earlier British type of flat, gibbed slides. There is evident, in most of the later machines, a careful study of the actual stresses in the structure, and an endeavour to economise material in the sense of removing it where unnecessary and putting it where it is really useful. The uprights of planers and boring mills and the column and arm of the radial drill are good examples.

Such finish as there is in twentieth

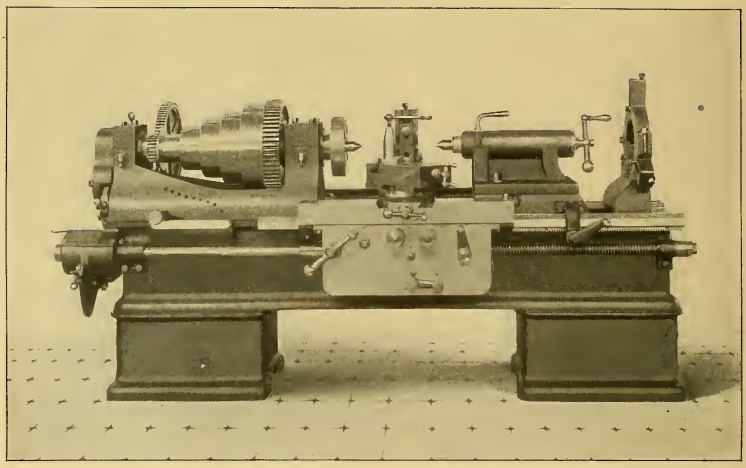


FIG. 7.—A HEAVY MODERN FORGE LATHE. MADE BY THE LODGE & SHIPLEY MACHINE TOOL CO., CINCINNATI, OHIO

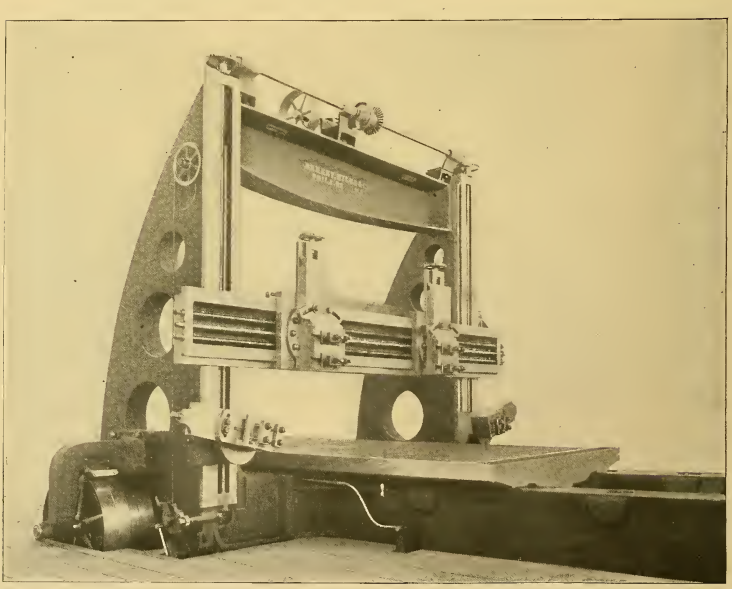


FIG. 8. - A PLANING MACHINE OF TO-DAY. BUILT BY MESSRS. BEMENT, MILES & CO., PHILADELPHIA, PA.

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century tools is more accurately done than formerly, and for this the grinding machine is largely responsible. While lathes and planers taking heavy cuts reproduce the errors of their own individualities, one or two grinding machines, with ways and spindles of special accuracy, will finish the work of twenty such, and do it well.

Perhaps what most impresses the observer in a machine shop of to-day is the enormous size and the massive construction of many of the machines. The lathe in Fig. 7 and the planer in Fig. 8 have not only a weight and size, but a power of removing metal which would by so-called portable tools, themselves large enough to require the services of 50-ton cranes for handling. It is Mahomet come to the mountain again.

Foremost as an agent in this progress towards the large and the heavy is the electric crane, without the assistance of which a planer like that shown in Fig. 8 would be helpless; and electricity alone has made the modern crane possible.

One cannot imagine cranes of such weight and speed handled by the clumsy mechanism in vogue only a dozen years ago. And, again, electric transmission has cleared the head room necessary for

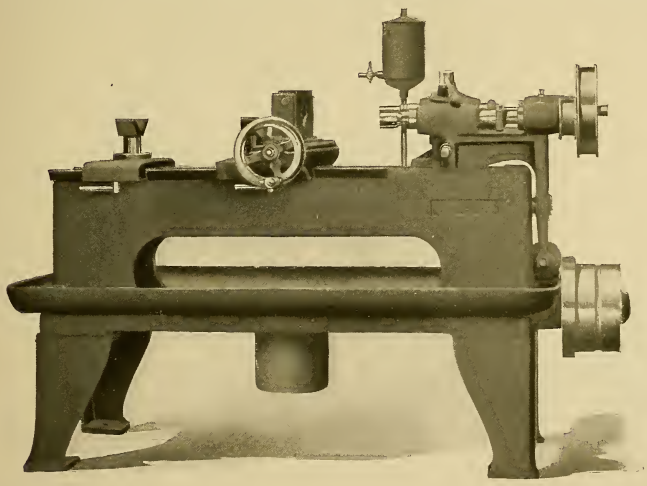


FIG. 9.—A GOOD EXAMPLE OF MODERN FINISH. A TWO-SPINDLE CENTERING MACHINE. MADE BY THE PRATT & WHITNEY CO., HARTFORD, CONN.

have astounded the mechanic of half a century ago. This all goes with modern ideas of concentration. Because the big engine and the big electric generator are more economical, we must have the tools to build them and the cranes to handle them.

Modern generators have already outgrown the possibilities of single tools, and we find field rings and armatures mounted on floor plates, both wide and long, laid out by transits and finished

cranes by substituting the individual motor for the overhead belt.

There is being wrought in all shops a gradual transformation in the character of the machines used which materially influences design. In the smaller shops the introduction of automatic special machinery, such as turret lathes and multiple drills, and the gradual substitution of milling machines for planers, are facts apparent to all. The multiplication of cutting points or edges in one

tool or in one machine is usually the motive for the change.

One instance of the kind shows another reason. The writer once asked a manufacturer why a certain machine was made duplex, at no apparent saving of iron or of floor space. The answer was that the trades union did not allow a man to run two machines, but there was no union law against running a machine with two heads.

In establishments doing heavy work there is a tendency to introduce large machines of vertical type, the boring mill taking the place of the wheel lathe for both boring and turning, and the vertical shaper or slotting machine supplanting its horizontal cousin.

Economy of floor space is doubtless one argument for the change, but better arguments are the greater accessibility of the work to touch or sight and the firm support afforded to chuck or table. Fig. 10 affords an example of the vertical type, and illustrates the beauty of a correct design, as well as the massiveness of modern machinery.

Modern problems in drilling in the larger shops are entirely out of reach of the ordinary drill press, its place being taken by the radial drill. The adaptability and range of this machine, its convenience in handling, and its strength and stability are guarantees of its permanence as a type. The machine illustrated in Fig. 13 shows great care in design and a careful study of the requirements of convenience and of strength.

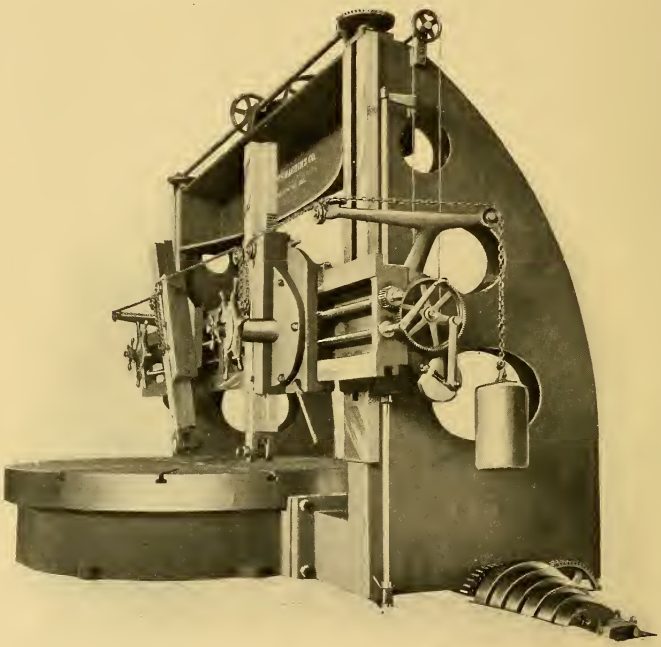


FIG. 10.—A VERTICAL TOOL TYPE. A HEAVY 12-FOOT BORING AND TURNING MILL. MADE BY THE BETTS MACHINE COMPANY, WILMINGTON, DEL.

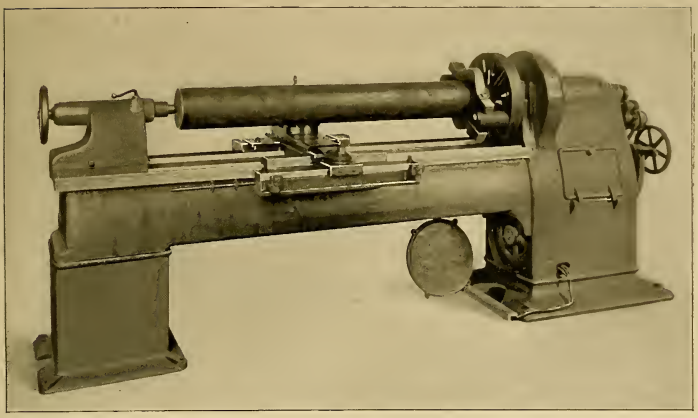


FIG 11.—THE ELECTRIC MOTOR DRIVING THIS LATHE IS HOUSED IN THE BASE OF THE MACHINE AS SHOWN. MADE BY THE GENERAL ELECTRIC CO., SCHENECTADY, NEW YORK

Multiplication of cutting edges is not by any means confined to the smaller tools, as may be seen by reference to the planer in Fig. 8. The four tool slides there, any two or all of which may be used at once, increase the capacity of the machine for turning out work and diminish the labour charge.

This increase of cutting power cannot be attained without a corresponding increase in the belt power and in the strength of the machine. When we consider that the use of air-hardening steel may more than double the output per tool, we understand why the horse-power rating of machine tools is larger than formerly.

This article would be incomplete without some reference to electric transmission, as that is to-day one of the principal modifying agencies in the design of machine tools. As has been before

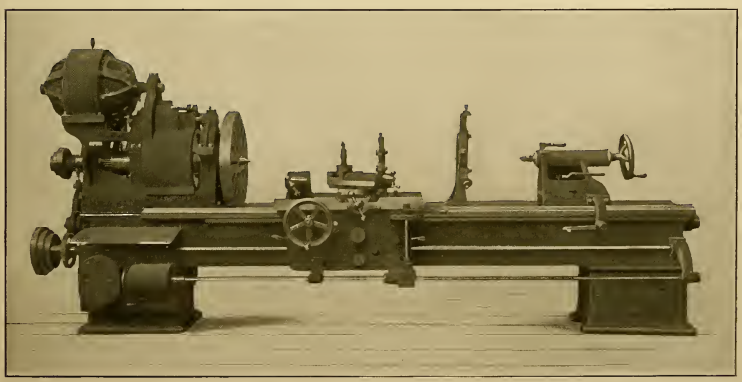


FIG.12.— A MOTOR-RIDDEN LATHE

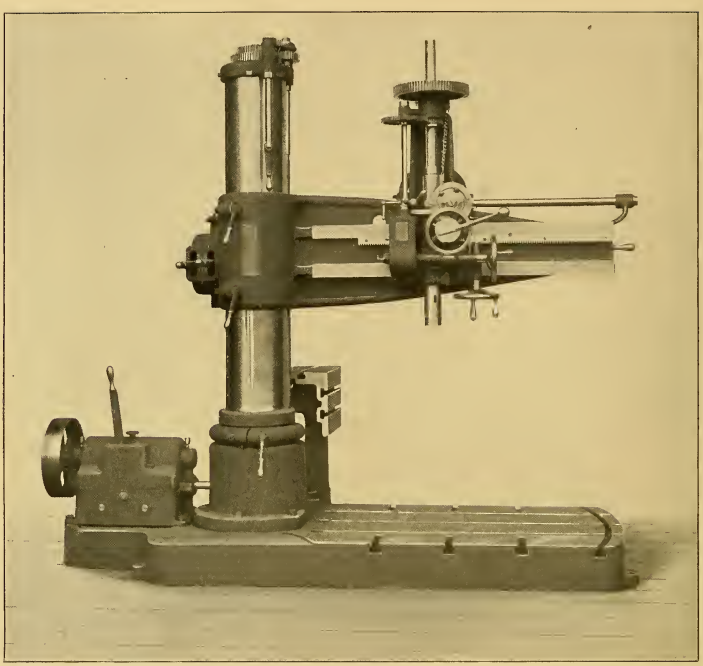


FIG 13.—A MODERN DRILLING MACHINE. BUILT BY THE BICKFORD DRILL & TOOL COMPANY, CINCINNATI, OHIO

intimated, it is electricity which has made possible the clear head room for cranes and the cranes themselves. Without some such method of handling work the existing mammoth boring mills and planers would be as helpless as so many babies waiting for food.

The tendency in electric drives for machine tools at present is toward direct current and variable-speed motors. In all establishments where there are a large number of machines of a similar character running at a constant speed the alternating current, fixed-speed motors offer a simple and economical system. The efficiency of such an arrangement in cotton mills, for example, has been repeatedly demonstrated. Many factories in which small iron and steel specialties are made in large quantities have adopted such a system with profit. In the ordinary machine shop there is another problem. We have here a variety of machines of different types and sizes, each one calling for a considerable range of speeds. If short line shafts driven by constant-speed motors are used, it is necessary to have mechanical speed control, involving a certain loss of efficiency and convenience and a multiplicity of belts. Planers and shapers have sometimes been grouped on long countershafts with clutches.

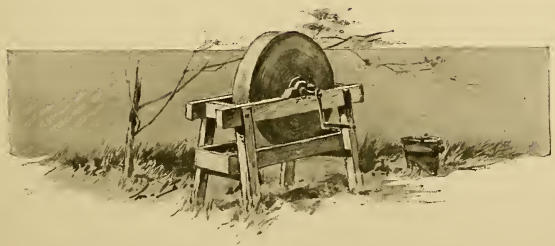
Individual motors on a three or four-wire multiple-voltage system, with speed controllers in easy reach of the operator, are undoubtedly more efficient on all machines which require two or three horse-power and upwards. There is a marked tendency in the direction of

their more extended use, even with smaller machines.

There is still much room for improvement in the adaptation of motors to machine tools. As at first the automobile looked like a carriage with the horse and shafts removed, so the lathe or planer does not yet answer in its design to the change from belt to motor (see Fig. 12). The relation between the machine and the motor reminds one of Sindbad and the Old Man of the Sea. The lathe or planer has a cast iron shelf supported by brackets, on which the motor may rest and be connected with the machine by belt, chain, or gears; but the general design of the frame has not been modified, and the machine seems to regard the motor as an interloper. The electrician complains that it is difficult to induce the machine designer to make any modifications or to meet him half way.

The lathe shown in Fig. 11 is an apparent exception, due perhaps to the fact that it was built by the electrician. It certainly shows that compactness and harmony of design which we have a right to expect, and may be a forerunner of the electrically-driven machines of the future.

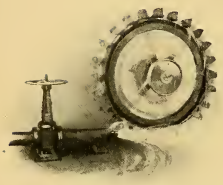
In summing up, it may be said that the designs of machine tools in this beginning of a new century are an improvement, practically and artistically, on those of twenty-five or even ten years ago. The machines have greater capacity and greater strength; they are more convenient and more quickly manipulated; they are more accurate in construction and in the work they do; while the absence of ornament and unnecessary finish and the distribution of the metal where it will best serve its purpose give dignity and character to the *tout ensemble*.



SMALL WATER POWERS WITH HIGH HEADS

FOR ELECTRIC LIGHTING

By Thorburn Reid



MANY years ago, when I was a very small boy, I built a dam, a canal and a water-wheel in a small meadow brook near my home in the country. The fall obtained was about 12 inches; the canal, about 6 inches by 6 inches in cross-section, was about 6 feet long, being dug out of the soft earth bank at the side of the stream. At the lower end of this canal a water-wheel was erected, consisting of a wooden shaft about 1 inch in diameter and 12 inches long, with ends whittled down to allow of their being inserted in gimlet holes in two upright posts driven into the earth, wooden paddles being inserted into gimlet holes in the middle of the shaft. This wheel was placed just over the fall at the lower end of the canal, and constituted the old-fashioned, lazy, easy-going "undershot."

My water-power plant never served any useful purpose in furnishing power, and my interest in it practically ceased with its completion. As a boy, my pleasure lay mainly in doing the work, and considerations of first cost, operating expenses, market for power developed, in a word, the commercial, as distinct from the purely engineering, elements, never intruded themselves into the problem to complicate it and disturb my happiness.

My perfect contentment in the work, wherein I was labourer, engineer, mechanic, and manufacturer all combined, has lingered in my memory with so pleasant a fragrance that to this day I can never pass a stream, be it never so small and insignificant, without scanning it for possible sites for small water-powers.

Some years ago during an engineering trip I came across a number of small water-powers, probably from fifty to one hundred horse-power each, some of which were used to drive mills, and others to supply light and power by electric transmission to various small towns and villages in the vicinity. Instantly it flashed into my mind that here were my boyish games being played by grown men in sober earnest, and that I might play them over again with all the old pleasure, much enhanced by the far larger scope of the work and its practical usefulness. As my time was then occupied with other work, much of it being concerned with water-powers of far greater capacity, but little attention could be devoted to following up this interesting possibility; but the few cases that I was able to work out showed such good results as to indicate a wide field of possible activity, which, as far as I know, has scarcely been exploited at all.

Perhaps the most interesting case was one upon which I stumbled while on a vacation at one of a number of mountain lakes. A small brook, fed by springs up on the mountain side, tumbled down a rocky bed through the woods and emptied into the lake a score of yards from a summer hotel. Having no instruments with which to measure the available fall or with which to obtain the flow of the stream, these had to be improvised from crude materials at hand. A carpenter's square and a stone hung on a string served for a level, one leg of the square being held in a vertical position by means of the stone and string plumb line, while I sighted along the other to a rod held for me by an oblig-

A MOUNTAIN STREAM WHICH SUPPLIED POWER TO A 25-K.W. DYNAMO FOR LIGHTING A SUMMER HOTEL

ing rodman, or rather rodwoman, my wife being my interested and more or less amused assistant. By these primitive means I found I could get a fall of about 150 feet in a horizontal distance of about 300 yards, measuring from the point where I had decided to place my dam down to the surface of the lake.

After much searching, a comparatively quiet stretch of stream was found, with the banks straight and the bottom of even depth, and the flow of the stream was measured by the float method. Twigs were placed in the stream at various distances from the bank, and the time required for them to pass from one string stretched across the stream to another parallel to the first and about 15 feet below it, was taken. The area of cross section of the stream was then carefully measured at several points between the strings and an average taken.

Owing to the smallness and shallowness of the stream, it was recognised that a comparatively large part of the water would be retarded by the irregularities of the bottom, and the cross section was, therefore, divided into ten imaginary channels, and the velocity having been determined for each, a large factor of safety was used, increasing as the depth of the channels decreased, and then the flow was calculated for each channel separately and all were added together. That the weir method of measurement would have been preferable to this in point of accuracy is undoubted; but I had neither the time nor the tools to build the necessary dam and weir, however much I would have enjoyed my old game of dam building.

The flow thus determined, after making liberal allowances for inaccuracies in the method of measurement, came out at about one cubic foot per second. Inquiry among the natives revealed the fact that the stream was very regular in its flow, except just after a heavy rain, and that at the time of my measurement it was about as low as it ever got to be. That its flow would be regular was to be expected, as its whole course lay through thick, virgin woods in which the accumulated mould of many years held water like a sponge when it rained and allowed it gently and gradually to seep down to the brook between rains. To afford an idea of the size of the stream, it may be noted that I jumped back and forth across it at will while getting the flow.

Allowing 15 feet loss of head from

friction in the 300 yards of pipe-line that would be necessary to carry the water down to the water-wheel at the lake shore, one cubic foot flow of water per second was equivalent to 15.3 horse-power. This again must be reduced by the loss in the water-wheel to about 11.5 horse-power available on the water-wheel shaft. This would supply about one hundred and twenty-five 16-candle-power electric incandescent lamps, and that was not enough for the needs of the hotel.

However, at the point chosen for the dam site the stream had cut out a deep ravine, with walls nearly perpendicular, varying from 30 to 40 feet in height, and cut back from the stream so as to be from 40 to 50 feet apart. A dam, 40 feet high and 50 feet long, would back up the water for a distance of about 100 feet. A few measurements with a tape line and levelling rod and level (the carpenter's square and plumb line again) gave sufficient data for a conservative estimate that this pond would impound about 60,000 cubic feet of water, requiring, with a normal flow of one cubic foot of water per second, 60,000 seconds, or nearly 17 hours, to fill up. Thus the water flowing during the day, when few lights would be required, and, therefore, little water used, would be stored up in this pond to be drawn upon at night, when all, or nearly all, the lights might be burning at once.

In such a hotel a few lights might be burning during the day in dark places, but it is not until between six and seven o'clock in the evening that any large lighting load begins to come on. From then on to about ten or eleven o'clock the lighting load is at or near its maximum. Lights are then rapidly turned off until, about twelve o'clock, nearly all are turned off, except the few which are left burning all night in halls and such places. Thus the maximum load does not last for more than about three hours, from seven until ten o'clock, and then it rapidly decreases till about twelve, when it reaches its all-night condition.

Sufficient water, then, to supply the maximum demand for power for four hours would be ample under such conditions; but special occasions, when a dance or other entertainment is given, must also be allowed for, when the ball-room and parlours may be lighted for two hours longer. Since, however, the lights in the dining-room, kitchen, and the rooms of those guests who are attending the ball will not be lighted, one hour longer is ample to allow for such occasions. To supply this demand there would be 60,000 cubic feet of water in the pond, plus the flow of the stream during the six hours that light was required, amounting to about 20,000 cubic feet, or a total of 80,000 cubic feet. This stored water, then, would be enough to supply three times as many lights as the flow of the stream alone would supply, or a total for six hours of 500 lights, or nearly 3000 lamp-hours per night.

Since the average number of hours burned per lamp installed would not exceed two, or at most three, this would allow of an installation of from 1000 to 1500 lamps, which was far more than the hotel required. Making every allowance for brilliant illumination, not more than 600 lamps were needed, and of these, even on special occasions, it was safe to calculate that not more than 400 would be burning at any one time.

A dynamo capable of supplying 400 lamps thus would be ample, especially as such a dynamo would have an overload capacity that would enable it to supply 500 or more lamps for an hour or two if it should ever be necessary. The hotel has accommodations for about 300 guests.

Such a plant would consist of a 25-kilowatt dynamo, direct-current, direct-connected to a 40 horse power water-wheel of the impulse type, water being supplied to the wheel through a 12-inch wrought iron pipe 300 yards long. The dam could be made a timber crib filled with earth and stones and faced on its upper side with 2-inch timbers in two layers, breaking joints, and bolted together. Such a dam would be tight, would require little repairing, and would last for fifteen or twenty years. The power house would be a simple wooden

frame building, its outside being made to conform with its surroundings, and would cost very little. The whole plant, including the dam, pipe-line, water-wheel, dynamo, switchboard, wiring, lamps, and all accessories, complete and ready to run and furnish light to the hotel, would not exceed about $6500 in first cost.

The operating expenses of such a plant would include as fixed charges,—that is, charges that are mainly independent of the length of time during which the plant is in operation,—depreciation, repairs, taxes, insurance, and interest and as variable charges, supplies such as oil, lamps, etc., and the services of an attendant.

A liberal allowance for fixed charges was $900 per year, and as the hotel was open for only about three months in the year, the supplies and attendant together would come to not more than about $300, or a total operating expense for the season of three months of $1200. That this cost is much greater than that of oil lamps is undoubted, but the saving in insurance due to the far greater safety of the electric system, goes far towards offsetting the added expense.

It was possible, without any extra cost, except the first cost of the motors, to use electric power in the kitchen and laundry, as well as fan motors in the hotel, and to charge the storage batteries of electric launches and automobiles, this being done during the day time when current was not required for lighting.

The cost of a steam plant to furnish the same current would come to about $6000. The operating expenses, exclusive of fuel, would be about the same as the total operating expenses for the water-power plant, and the cost of the current would, therefore, be increased by practically the whole cost of the fuel required to generate it.

The water-power plant can be run during the day for power and for light in dark places in addition to being run at night at practically no increase in expense, since water costs nothing, while running the steam plant in the day time would mean the consumption of fuel, most of the energy of which, by reason of the light load, would be consumed in engine and dynamo losses. Again, the water-power plant can be started by the turning of a valve, while with the steam plant fire must be lighted under the boiler and steam raised before the plant can be started. It is scarcely necessary to cite further arguments to show that the water-power plant is preferable to the steam plant for its convenience, reliability, cleanliness and safety, even if its operating expenses had been considerably greater.

This plant has been described in such detail because it presents features making for commercial and engineering success which even engineers of much experience are almost certain to overlook on account of the smallness of the stream. The particular condition that made the utilisation of this stream feasible, despite the small amount of its flow, was the high head available, since the power that can be obtained from the flow of a given amount of water varies directly with the head. Again, the high head makes it possible to store up at slight expense and utilise practically the whole amount of water flowing during the day while the plant is not in operation or is running lightly loaded.

With low heads this is not generally possible, since the depth of the water above the dam would be a large part of the total available head, and, therefore, reduction in the level of the water in the pond would largely cut down the speed and capacity of the water motor, as well as the power that can be obtained per cubic foot of water. Thus with a low head the water above the dam can be drawn down only a comparatively short distance before the reduction in the available head would cause trouble. Only a foot or two of the depth of the pond can generally be utilised in such cases, and the area of the pond must be very large if it is to serve as a reservoir for much power, both on account of the small amount of power generated per cubic foot of water and because only a small part of its depth can be utilised.

This great storage capacity of small streams with high heads makes possible

the utilisation of many times the average power of the stream, provided this maximum power is required for only a few hours out of the twenty-four, which is nearly always the case with electric lighting plants.

Again, the use of high heads reduces the amount of water to be handled, and thus reduces the cost of dams, raceways, pipe-lines, water-wheels, etc. Finally, floods affect such plants very slightly, while the rising of the water in the tail race during floods often very seriously impairs the total available effective head when that head is low to begin with.

In the case described above it was not necessary to buy any land or water rights, as the land through which the stream flowed from the dam to the lake belonged to the hotel; but the cost of such rights, where it is necessary to buy them, would usually be trifling, since the water would not be valuable for any other purpose, and very little land would be needed.

It is readily seen that the field for such plants as the one here described is necessarily limited to more or less mountainous regions; but it is in just such places that other sources of light and power are costly and inconvenient on account of high transportation rates, poor and hilly roads and danger from fire.

The water-powers already developed that I spoke of early in this article as having first drawn my attention to the possibilities of small streams for this purpose, all utilised comparatively low heads, and their development would not have been commercially practicable under the condition of operation for three months of the year only, as was the case with the hotel plant above described. This plant could have been in operation for the whole year, or four times as long, at a yearly cost of less than twice as much as was required for three months, since the main items of expense, the fixed charges, would be little, if at all, increased. Thus the average cost of current would have been reduced more than 50 per cent.

The writer has seen a large number of such small streams with high heads evidently capable of being profitably utilised in the manner described; but I know of but one that has been so utilised, and that one in a very imperfect and, from an engineer's point of view, very slovenly manner. The dam leaked to such an extent when I saw it that although no water was flowing through the pipe-line, none flowed over the dam; all of the water of the stream leaked through the dam. The pipe-line was of poor design, and in a distance of about 1000 feet showed about forty leaks. In spite of these and other obvious defects, the plant did fairly well what its owner required of it.

To sum up, then, the power of small streams with high heads can, by means of storage of water, be multiplied many times whenever the maximum power is required for only a few hours out of the twenty-four. The cost of developing and utilising such powers will be low by reason of the small amount of water to be handled and because the water of such streams and the small amount of land required are generally valueless for any other purpose. Such plants are generally reliable in operation, safe and clean, and do not require highly skilled attendance. The cost of light thus obtained will usually be much higher than by the use of oil lamps; but this will be largely offset by the attendant advantages.

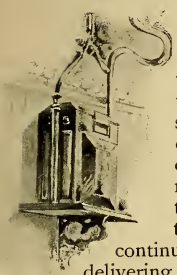
In conclusion, a word of caution should be added for any one who may contemplate installing such a plant. One of the most prolific sources of trouble, even sometimes of complete failure, in the utilisation of water-powers lies in the irregularity of the flow of the stream, and great care should be used to learn from all available sources what is the lowest stage the water ever reaches in the driest season. Careful measurements of the flow should also be taken and liberal allowances made for droughts.

Where much of the course of the stream lies through thick woods, its flow is likely to be fairly regular, but where its course lies mainly in the open, avoid it, since then in a dry season it is likely to run almost dry.

DISTRIBUTING ILLUMINATING GAS AT HIGH PRESSURE

SOME EXAMPLES FROM AMERICAN PRACTICE

By F. H. Shelton, Consulting Gas Engineer



IT is a rather curious fact that until very lately the distribution of illuminating gas, throughout the century since its discovery and commercial use, has been on the same lines and methods in vogue from the beginning. That is to say, the universal and continuous practice has been, in delivering the finished gas from the works to the consumer's premises, to do so through relatively large pipes, at low pressures. It is astonishing to note that most illuminating gas is put out at a pressure of only 3 to 7 inches of water, or but one-ninth to one-fourth of a pound "steam pressure."

When it is remembered that water and steam are safely distributed in the largest cities at pressures in the hundreds of pounds, and that natural gas is conducted through many towns and cities at scores and hundreds of pounds, that Pintsch oil gas is safely handled for the lighting of innumerable railway cars at about two hundred pounds pressure, and that refrigerating fluids, compressed air, and other liquids and gases are also daily safely handled at high pressures in public places, the strangeness in these days of continuing to handle illuminating gas at but a fraction of a pound is most evident. Moreover, this low pressure means large conductors for given capacities, and in addition to the cost of large pipes (for the especially growing fuel trade of gas companies), the physical difficulty of inserting large new pipes in many streets, already much occupied beneath the surface, is also to be reckoned with. In further line of such thought the ability to connect and operate adjoining work by an inexpensive small-size, high-pressure gas line,—where the investment of an expensive large line would be prohibitive,—suggests attractive possibilities in consolidation and economy of operation.

The writer, in brief, about three years ago reached the conclusion that there was neither logical, mechanical, nor commercial reason why illuminating gas should not be handled at a number of pounds and at relatively high pressure precisely as natural gas is, and, opportunity arising to demonstrate his convictions, he laid the first line of this character between Phœnixville and Royersford, in Pennsylvania, in December, 1899. The gas works at the latter place were thereupon closed down, and have never since been run, all the gas having since been made in Phœnixville, the necessary portion for Royersford being pumped there through a pipe but 3 inches in diameter and 23,015 feet long, or about 4⅓ miles, at about twenty pounds pressure. The equipment worked so satisfactorily that within a few months more lines were started elsewhere, and to-day there are twenty-five or thirty operated, or being built.

High-pressure practice has thus already become fairly established and is now a recognised method, very suitable for certain conditions. Without describing all the lines constructed, it is of interest to point out the four conditions of the gas business for which it is particularly applicable and convenient.

1.—Consolidation of manufacture by

connecting adjoining works, enabling concentration of operation, where the cost of old practice large, low-pressure mains would be prohibitive.

2.—Extension of territory by inexpensive high-pressure feeders to near-by villages, etc., enabling extension of gas service of an existing company to communities that would not otherwise get it if the cost of large mains were involved.

3.—Development of ordinary general suburban territory, thinly settled, that would not justify usual mains.

4.—Reinforcement of overtaxed old mains by high-pressure "boosting" pipes at much less expense than the cost of usual new trunk line pipes.

The connection of adjoining works is well exampled by the instance above mentioned. The second installation by the writer is a further case, wherein by means of a 6-inch main nine miles long, with an offshoot of 4-inch size, five and a half miles long, the local gas works at Darby and at Media, Pa., have been shut down, and all the gas for a territory about twelve miles long, with one hundred and twenty miles of main, is made at the main Chester works of the Suburban Gas Company, of Philadelphia. Concentration of make may again be seen in the instance of the Bergen County Gas & Electric Company, of Hackensack, N. J., dispensing with the running of the Rutherford neighbouring plant by means of a 5-inch high-pressure pipe-line, six miles long, connecting it to the main works for supply. The largest installation of a high-pressure main so far laid down in the United States for illuminating gas and for connecting adjoining plants, is that recently completed by the South Jersey Gas, Electric & Traction Company, in which instance a 12-inch main, about thirty-five miles in length, connects Camden and Trenton, N. J., and the intervening towns of Burlington, Bordentown, Mount Holly, Riverton, and several others formerly served by small local plants.

The possible extension of an existing gas supply to small neighbouring towns, because of the small investment required and successful working of high-pressure pipes, is well instanced by the case of the Rivershore Gas Company, that primarily served Riverton, N. J., only, yet by high-pressure pipes of but 3-inch size was enabled to send gas to Moorestown, three miles in one direction, and to Riverside, two and one-half miles in another, and thus largely increase its possible customers.

In the same way the North Shore Gas Company has extended its service from Waukegan, Ill., south about twelve miles to Fort Sheridan, Lake Forest, Highland Park, and other towns, opening up to the convenience of a gas supply small towns that but for high-pressure working would not yet have it.

In the development of thinly scattered suburban territory the instance of the Suburban Gas Company, of Philadelphia, is most conspicuous. That company, operating in seventeen scattered boroughs of from but 200 to 3000 population each southwest from Philadelphia, was confronted with the enormous expense of ordinary size mains to cover the great distance involved, to secure, at best, but scattered business. The situation was met by using 3, 4, and 6-inch trunk lines and 1¼-inch laterals, conducting gas at twenty pounds pressure, instead of the usual 12, 16, and 20-inch trunk lines, with 4-inch laterals operating at low pressure. For about two years this departure in main systems has been working very well, and to-day the system comprises about fifty miles of pipe, serving about 2000 customers.

The reinforcement of insufficient pressures on old mains is well illustrated in the case of the New Orleans Lighting Company. That company operates about 200 miles of main in the city of New Orleans, La., mostly laid a generation or more ago, working at the usual 3-inch pressure. The company recently doubled its gas-cooking and fuel trade, and these old mains proved insufficient. To lay ordinary 24-inch new trunk lines would have cost about $125,000. In lieu of that 4 and 6 inch high-pressure mains, extending in opposite directions from the works two and three miles, respectively, were in-

stalled, with a pumping plant that delivers through these reinforcing pipes almost as much gas as goes out through the low-pressure mains, and the expense of this was but $50,000, to say nothing of the greater quickness in getting relief and ease in laying, in busy streets, by using but a 6-inch pipe.

A still further especial adaptation of high-pressure gas will probably be found in the growing use of incandescent gas lamps of the Welsbach type, wherein high candle-powers are easiest obtained by burning the gas under considerable pressure. At present this is mostly accomplished by individual and local gas compressing machines, or by complex burners and lanterns. If gas under high pressure were generally available, the use of gas for high candle-power lighting would be greatly enhanced and efficiencies probably largely increased. In numerous workshops, too, gas is burned in sundry forges and ovens to best advantage at higher than usual pressures, and to meet this demand high-pressure distribution would well lend itself. Already the Mohawk Gas Company, of Schenectady, N. Y., is serving gas at high pressure for such reasons to the General Electric Company's shops. Numerous other installations, from New England to California, could be cited, further evidencing the usefulness of high-pressure work.

The mechanical carrying-out of high-pressure delivery is simple, involving no new principles, but chiefly care and details. The fundamentals are an efficient gas compressing and pumping plant, a tight pipe-line, and reliable governors, or regulators, for properly releasing the gas at ordinary pressures at the points where it is to be consumed. The compressing pumps usually used are identically the same as those used in the many purposes of compressed air, barring a few modifications, because of handling gas. They are, of course, equipped with a suitable governor for controlling speed and pressures.

The pipe-lines are usually,—and should invariably be,—of wrought iron or steel, and not of cast iron, to minimise chance of breakage, and for the same reason cast screw fittings are omitted, so that contraction and expansion may occur without danger from brittle points in the line. These wrought iron lines are usually of rather heavier weight than ordinary pipe, have finer and better threads and couplings, and are especially coated, externally, with sundry preservatives against rust or electrolysis.

At the far ends diaphragm regulators of various designs are generally used, of the same kinds employed in the control of natural gas. These, sometimes singly, sometimes tandem, for very delicate control, and sometimes in pairs for ease of examining and cleaning, cut down the pressure of the passing gas and deliver it at whatever pressure is desired, and for which they are adjusted, no matter how many pounds or how much variation may exist on the high side. Their work is perfect. Smaller ones are used to reduce the pressure for customers whom it may be desired to serve along the line of the high-pressure main. In this case the service pipe should also be supplied with such arrangement of safety seals and cocks as will absolutely ensure not only a proper vent for surplus gas, if the regulator should, perchance, not work, but no possibly greater amount of gas in the consumer's premises than would come from an ordinary low-pressure service. It is obviously desirable that no undue pressure should possibly reach the gas meter, and that the consumer's hazard should not be increased because of using high-pressure gas, and by a simple device, designed by the writer, this result is perfectly attained.

High-pressure transmission of illuminating gas has come, and, unquestionably, come to stay, as may easily be seen from the description above of its work already in evidence in but thirty-six months. As far as the writer knows, each and every installation so far is working with eminent satisfaction, and the prediction is made that, as the low investment, elasticity, convenience, and economy of operation of such method of operation is more fully realised, the adoption of the system will rapidly increase.

THE GREAT EASTERN RAILWAY "DECAPOD"

By James Holden, M. Inst. C. E., M. Inst. M. E., Locomotive Superintendent of the Great Eastern Railway, London

JUST a century ago, in the year 1803, Richard Trevithick, the captain of a Cornish mine, constructed the first engine to run upon rails of which there is any known record. Fig. 1 shows Trevithick's engine, than which the world has never known any more revolutionising invention. Fig. 2 shows on the same scale how the Cornishman's engine has evolved, so far as the Great Eastern Railway is concerned, and what it looks like "on the morn of its hundredth year." It is the most powerful locomotive ever built in Europe, —the most powerful tank engine in the world.

"But why should the Great Eastern Railway require the services of such an Anak?" is a question frequently put to the writer. The needs of the Great Eastern suburban traffic demand it. Prior to the era of railways everybody but the most wealthy lived in town; today, everyone but the poorest lives in the country, albeit his work continues to be urban. Into every great terminus an overwhelming tide of humanity flows six mornings of the week and ebbs in the evening. On no other British railway does this vast tidal wave assume the gigantic proportions it acquires on the Great Eastern; 180,000 persons daily surge in and out of Liverpool Street Station, in London, and it is the proud boast of the company that on no other railway are they so punctually carried, in spite of the fact that on no line are there so many difficulties to be overcome. Perhaps the greatest difficulty has arisen in consequence of the very excellence of the catering. Ample and prompt train service has attracted populations, resulting in periodical congestion of certain trains in some of the more popular districts.

Two of the most densely peopled branches are the Enfield and the Walthamstow. When about fifteen years ago it was proposed to quicken the service on the Enfield line, it could not be done by fast running between stations, but was accomplished by engines, about one hundred of which are in running, specially designed to afford rapid acceleration from rest. The gross load was 200 tons. The acceleration obtained was 0.97 feet per second per second, or a speed of 20 miles per hour at the end of thirty seconds.

But the demand increased with the supply. To meet it the carriages were widened to the full extent of the load gauge by cutting them in the centre and inserting a strip.

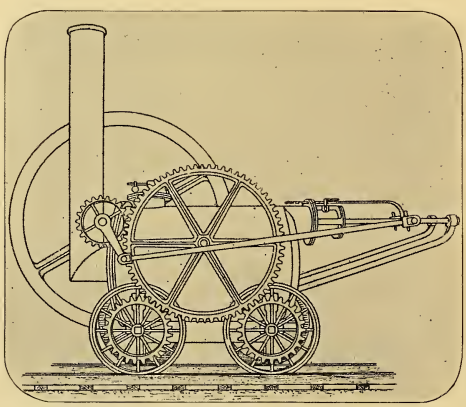


FIG. 1.—TREVITHICK'S LOCOMOTIVE OF 1803

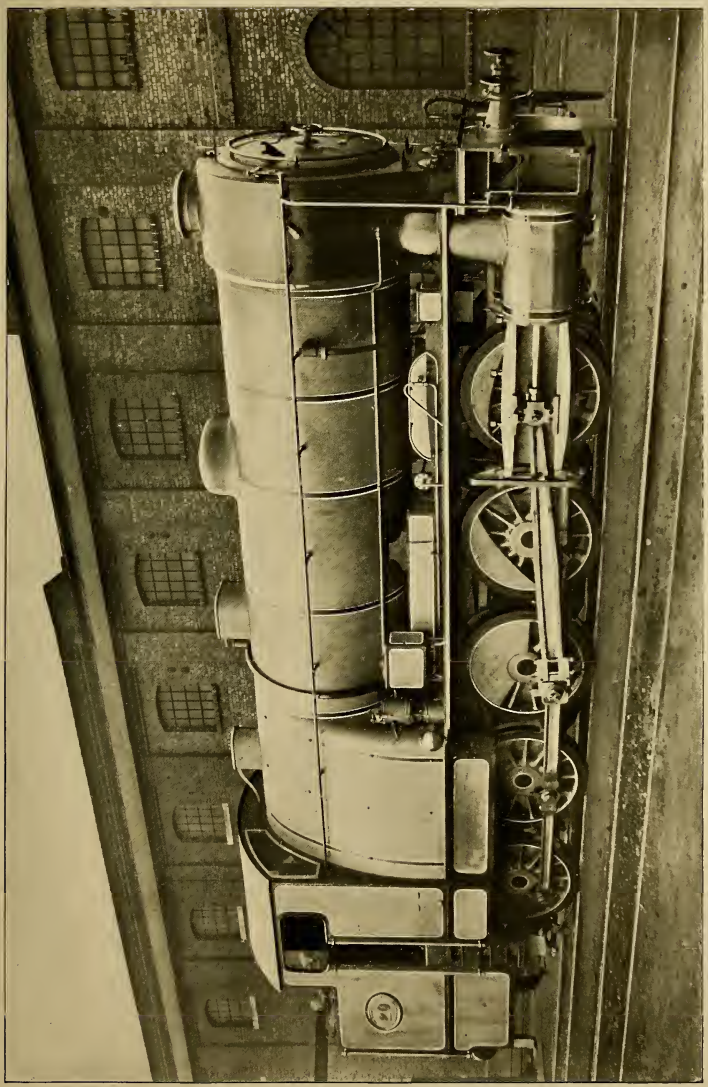


FIG. 2.—THE GREAT EASTERN RAILWAY DECAPOD. THE MOST POWERFUL TANK ENGINE IN THE WORLD. THREE CYLINDERS, NON COMPOUND, 18½ × 24 INCHES. TOTAL WEIGHT, 78 TONS

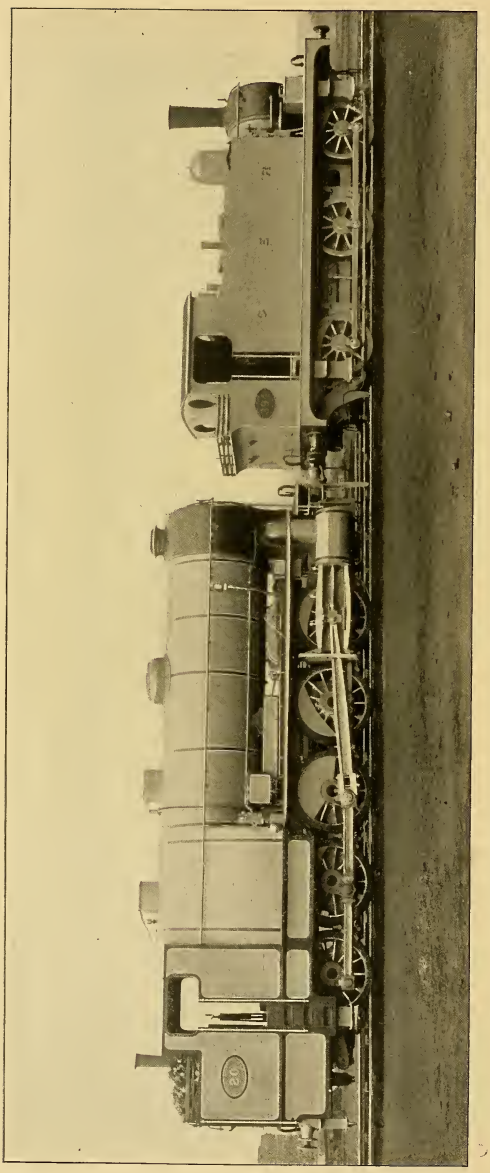


FIG. 3.—A VIEW OF THE "DECAPOD" AND ONE OF THE PRESENT GREAT EASTERN ENGINES TAKEN TO THE SAME SCALE

This enabled the train to accommodate 22 per cent. more passengers, giving each person the same room as before. The process of widening is still in full swing, and will not be completed before the end of 1904; but on December 31, 1902, fifty-two wide trains were running in the suburban district, affording 7000 more seats than when they were of ordinary width. When all the suburban carriages are wide the comparative increase of seats will be 21,000. These wide trains are only slightly heavier than the narrow ones, the excess, even when loaded with the full complement of passengers, not amounting to more than twelve or fourteen tons. An increase of boiler pressure from 140 to 160 pounds per square inch, with a small increase of grate area, enables the original acceleration to be maintained without any other alteration of the engines.

The British public has for some time past been assiduously informed that railway directors are ornamental elderly gentlemen who attend board meetings and receive fees for work which they conspicuously neglect. The writer was for twenty years on the Great Western Railway; he has been for eighteen years on the Great Eastern. His experience has been that British railway directors are hard-headed, capable business

men, who know what they want and mean to have it,—men with a habit of looking ahead, profiting by the experience of yesterday, and anticipating the possible problems of to morrow. They are not, as it is the fashion of their irresponsible critics to assert, either ignorant or negligent of American and Continental methods. But knowing, as they do, that local practice is almost invariably the outcome of local requirement, they are of opinion that the methods adopted in a country where one set of conditions rules are not necessarily equally suitable to meet the requirements of another country, where a totally different set of conditions has to be considered and provided for.

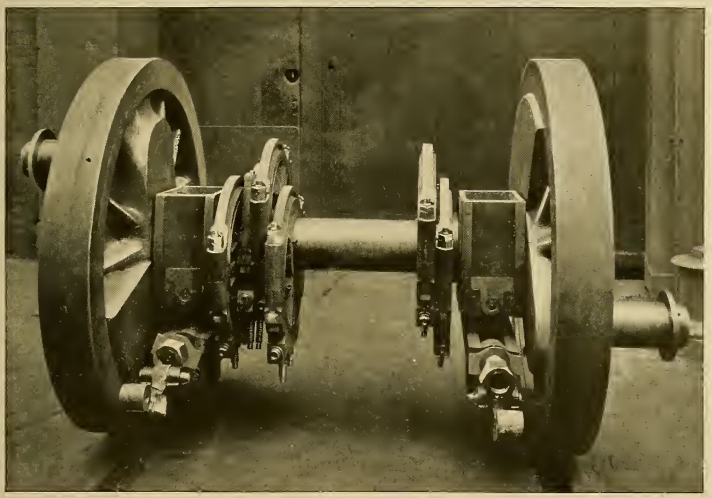


FIG. 4.—THE FLANGELESS CENTRE WHEELS WHICH EASE THE ENGINE ON CURVES

After this manner, *inter alia*, the future of the Enfield and Walthamstow branches has been considered. Reports have been made of overcrowding in certain trains. There is no hour in the day when there are not more seats than passengers but there are congested moments when there are more passengers than seats. The problem would be easy of solution if it were possible to persuade the travellers to spread their numbers over two or three of the available trains instead of mainly concentrating them on one. But the passenger cannot be coerced,—he can rarely be persuaded,—into travelling by any train other than the one he prefers. He refuses to travel by one starting four minutes earlier, and he will stand in the train of his choice rather than wait for a seat in one starting four minutes later. His train goes away crowded, while the following train leaves with a large margin of unoccupied places. To provide a seat for every passenger, no matter what train he may select, is the object of the management, and if the increase of population in the suburban area served by the Great Eastern Railway is to continue in the proportion that it has done for many years past, and is still doing, a corresponding increase of accommodation must be provided. It is not possible under existing conditions to get more trains over the busiest lines, and three methods of solution offer themselves.

The first and most obvious is to build

FIG. 5.—ONE OF THE COUPLING RODS FOR THE TRAILING WHEELS

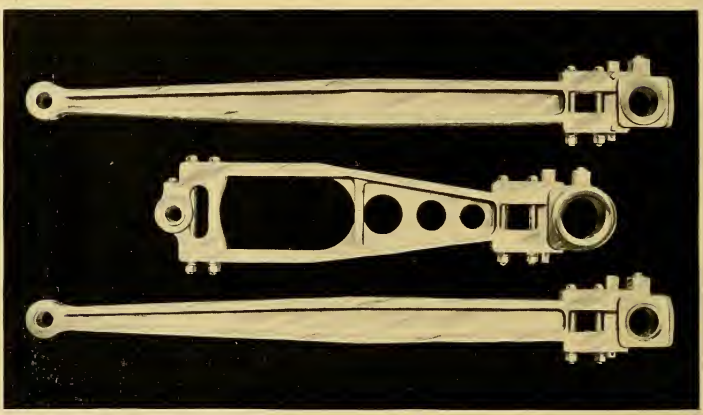


FIG. 6.—TO CLEAR THE LEADING AXLE, THE INSIDE CONNECTING-ROD IS MADE WITH AN OPENING WITHIN WHICH THAT AXLE ROTATES

another line. But the expense of this through the crowded city is so enormous as to be prohibitive. It is hardly likely that the capital would be forthcoming if it were attempted. The second is the very popular and fashionable remedy of electrification. An electric tube-railway is not without its disadvantages and drawbacks. The capacity of a tube is gauged by the capacity of the lifts, and nowhere is congestion set up so readily and so virulently as in a popular tube-railway.

The problem of tube ventilation also has yet to be solved. For these and other reasons an electric tube under the existing railway, although getting rid of the very large and important factor involved in the purchase of surface property, is not an ideal solution.

Electrifying the existing system, with trains of twelve carriages running at two-minute intervals, as compared with the existing fifteen-carriage trains running at four-minute intervals, has been seriously proposed as a remedy. It is in many respects more feasible; but the conditions that present themselves are so complicated, and the numbers to be accommodated are so huge, that existing electric railways are, in comparison, as dwarfs to a giant. It would at best be a costly remedy, assuming the hypothesis that it would be adequate.

Nevertheless, the fact that the Great Eastern Railway Company is asking for

Parliamentary power to electrify portions of its system disposes of the allegation sometimes heard that the directors are opposed to electrification. They are quite prepared to electrify when the time arrives. Meanwhile, the North-Eastern and the Lancashire & Yorkshire railways (not to mention the Metropolitan and Metropolitan District) are actually electrifying portions of their respective lines.

The Great Eastern Railway Company is not wealthy, and if the relatively small expense of improved steam traction will enable it to provide promptly the additional facilities that the public convenience demands, the directors will, at a later date, be able to avail themselves of the experience afforded by the equipping and working of those railways which are actually electrifying, and will also be able to adopt any improved methods which the rapid advance of electrical knowledge may by that time have placed at their disposal.

Under these circumstances, the proposal of a third alternative was made. This alternative involves the continuance of steam traction; an increase in the length of the trains to seventeen, or possibly eighteen, carriages; and an increase of 50 per cent. in acceleration. Thus, with a gross load of 300 tons, the train, at the expiration of thirty seconds after starting, will have travelled one-eighth of a mile, its speed at that instant being thirty miles per hour. This, in terms of acceleration, gives 1.46 feet per second per second, the trains following each other at three minutes' intervals.

The cost of surface electrification has been variously estimated; the lowest figure is about one million sterling. To test the effectiveness of electrification involves the expenditure of the entire amount. The estimated cost of the proposed accelerated steam traction is much lower. The engines will be heavier than was at all reasonable to anticipate when the line was constructed. Their introduction will, therefore, involve some expenditure on the line in

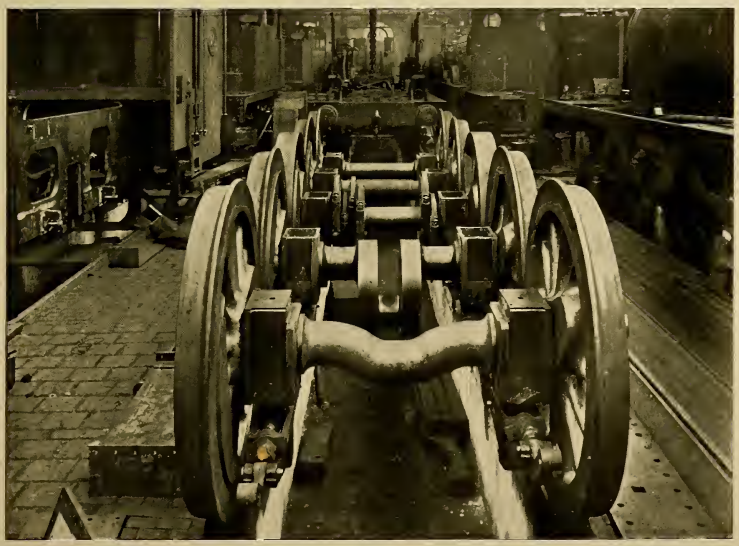


FIG. 7.—THE INSIDE CONNECTING-ROD OPENING SHOWN IN FIG. 6 IS KEPT NARROW BY BENDING THE LEADING AXLE, AS HERE ILLUSTRATED

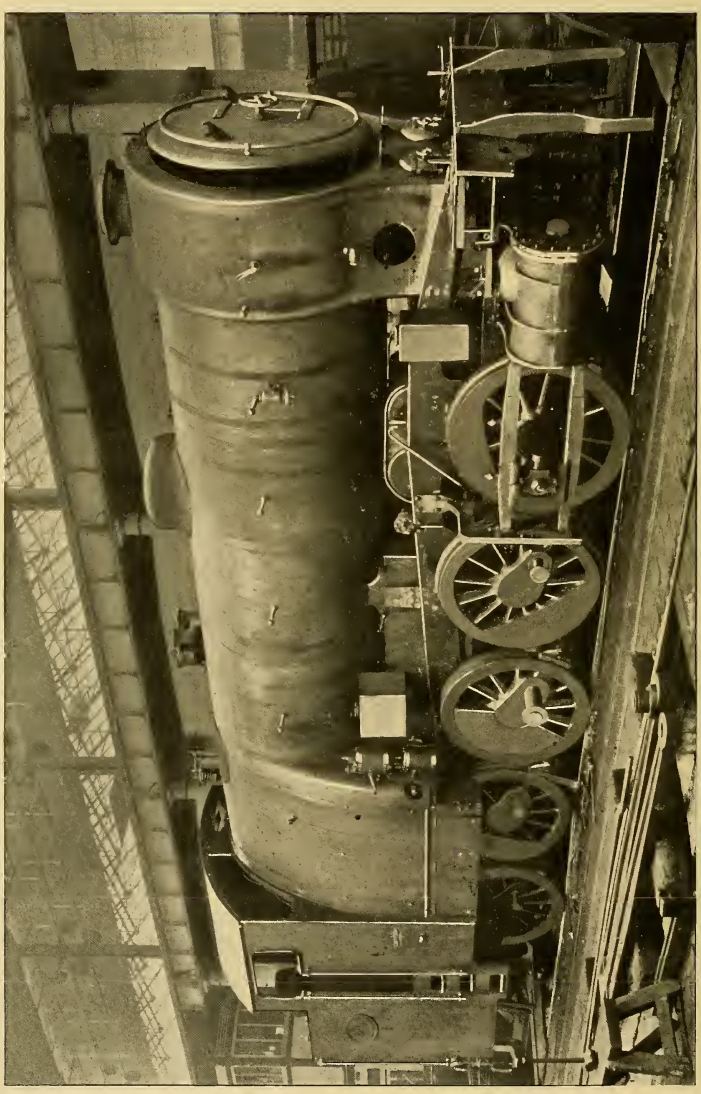


FIG. 8.—A CONSTRUCTION VIEW OF THE ENGINE

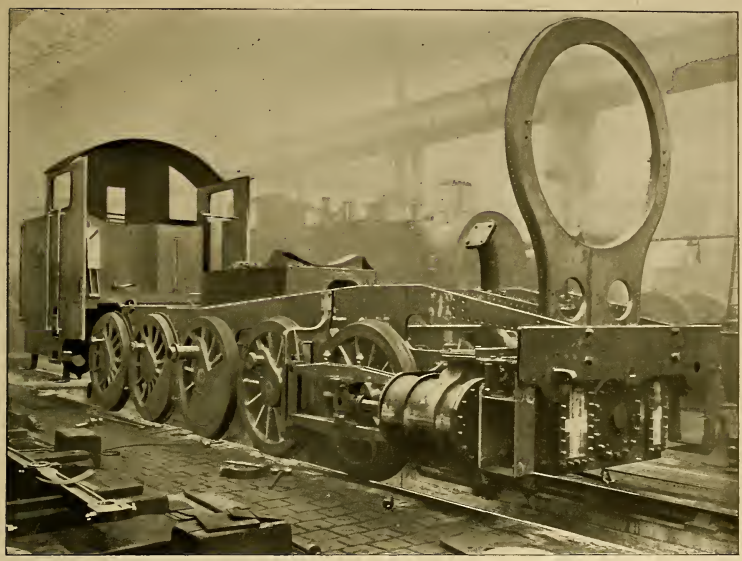


FIG. 9.—A VIEW BEFORE THE BOILER WAS MOUNTED

order to maintain the large factor of safety which the engineer of a railway very properly insists upon. It is assumed that this will amount to £70,000, and the cost of the necessary engines to £120,000.

But the effectiveness of this scheme can be demonstrated by simply building one of the proposed engines and proving by actual experiment that it is capable of doing what is claimed. The cost of such an experiment is estimated at £5000. Such is the *raison d'être* of the "decapod." Now let us see what she looks like, how she will be able to perform the task imposed upon her, how she differs from other engines. Fig. 3 is a view of the decapod and one of the present engines working the service, taken to the same scale. The most noticeable difference is in point of size.

One of the greatest difficulties in connection with the design was the comparative smallness of the load gauge on British railways, which restricts height to 13 feet and width to 9 feet. On American railways the respective figures are 16 feet and 10 feet 6 inches. It will be quite evident how this compression of the British load gauge must be reflected in the respective designs of British and American engines.

The most powerful American tank engine that the writer is acquainted with is working on the New York Central & Hudson River Railroad. The following table shows some of the important particulars of the decapod as compared with this engine:—

	G. E. R.	N. Y. C. & H. R. R.
Boiler pressure	200 lbs.	200 lbs.
Cylinders,		
Diameter	18½ ins.	20 ins.
Stroke	24 "	24 "
Number	3	2
Driving wheels, diameter	54 ins.	63 ins.
Mean tractive effort, (M. E. P. equal to 80 per cent. of boiler pressure)	36,507 lbs.	24,381 lbs.
Adhesion at 500 lbs. per ton	39,125 "	31,500 "

Another difficulty has been to obtain, without undue weight, sufficient adhesion for the work demanded. This has been obtained by distributing the weight over ten wheels actuated by three cyl-

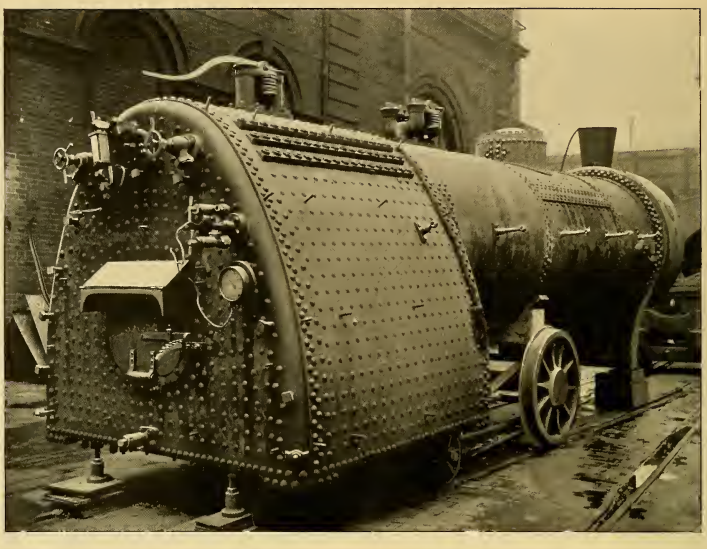


FIG. 10.—A VIEW OF THE BOILER ALONE

inders. and also by a special and quick-acting sanding gear. The cranks are arranged at angles of 120 degrees. The advantage of this arrangement over two or four-cylindered, non-compound locomotives with cranks at 90 degrees is that although the mean tractive effort is equal for the two engines, the maximum crankshaft torque is considerably less in the three than in the two or four-cylindered engine. Such a three-cylindered engine is also a superior starter to a two or four-cylindered engine with cranks at 90 degrees.

The sand is forced under the wheels by an air blast from the main Westinghouse brake reservoir. The reservoir is divided into two portions joined by an ordinary non-return valve, so that the total contents of both portions may be available for brake purposes, whilst any quantity may be used for sanding without the fall of pressure operating the brakes. The pumps deliver air on the sand side of the reservoir and through the non-return valve to the other side, this side being connected to the brake train-pipe. It was thought advisable, when balancing, to depart somewhat from usual practice; the whole of the reciprocating masses have been balanced, instead of the usual two-thirds. The valve motion has also been taken into account. The method adopted has been to calculate a weight for each wheel to balance masses revolving about the axes of each wheel independently; then to obtain a resultant weight to balance all the reciprocating masses, and, as far as possible, equally distribute this reciprocating balance in the various wheels; and, finally, to calculate for each wheel the resultant of the allotted reciprocating balance, increased by the already obtained rotating balance. Most of the available space in the centre wheel is occupied by rotating balance; consequently, a certain portion of reciprocating balance which would, if space permitted, have been located in the centre wheel, has had to be allotted elsewhere. To minimise as far as possible the amount of centre wheel balance, the weight in these wheels was cast hol-

THE DECAPOD COMPARED WITH OTHER ENGINES

	Nord.	Claud Hamilton.	Decapod.
Cylinders, Diameter	13.38 ins. (high pressure) 22.04 ins. (low pressure)	19 ins.	18½ ins. (three cylinders, non-compound
Stroke	25.19 ins.	26 ins.	24 ins.
Driving wheels, Diameter	6 ft. 8 5-16 ins.	7 ft. (four-coupled)	4 ft. 6 ins. (ten-coupled)
Boiler pressure	228 lbs.	180 lbs.	200 lbs.
Total heating surface	2,244.5 sq. ft.	1,630.5 sq. ft.	Tubes 2,878.3 sq. ft. Firebox 131.7 " Total 3,010.0 "
Grate area	29.5 "	21.3 "	42 sq. ft.
Total weight	107 tons	80½ tons	78¼ tons.
Weight on driving wheels	32.3 "	33 "	78¼ "
Tractive Power (M. E. P.—80 per cent. of boiler pressure)	20,007 lbs (as a compound) 25,860 lbs. (as a non-com'd)	16,090 lbs.	36,507 lbs.
Adhesion at 500 lbs. per ton	16,150 lbs.	16,500 lbs.	39,125 lbs.

low, the chamber thus formed being run in with lead through holes in the periphery of the wheel before the tire was put on, lead being nearly 50 per cent. heavier than steel.

To prevent rocking and pitching and the variations in wheel load incident to inclined cylinders,—a serious consideration where wheel load is necessarily restricted,—the cylinders have all been placed horizontally. The outside cylinders drive the third axle from the front; the inside cylinder drives the second axle from the front. To clear the leading axle, the inside connecting-rod has been designed with an opening, as shown in Fig. 6, in which the leading axle rotates.

As all the axles rotate in unison, a considerable narrowing is obtained in the connecting-rod opening and a sensible reduction in the weight of the reciprocating masses by bending the leading axle, as shown in Fig. 7. To ease the engine on curves, the centre wheels are flangeless and one inch wider, as shown in Fig. 4, and the trailing wheels have three-quarters of an inch side play in either direction. The coupling rods to these wheels are shown in Fig. 5. They are provided with a vertical joint at one end and a swivelling bush at the other.

Figs. 8 and 9 are views of the engine taken at intervals whilst building. A comparison of the decapod with the most recent Great Eastern express type, the "Claud Hamilton," and also with the famous De Glehn compounds of the Northern Railway of France, may be of

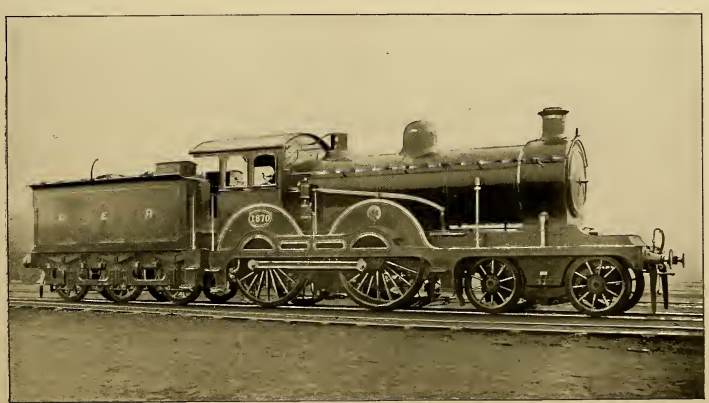


FIG. 11.—THE "CLAUD HAMILTON," A RECENT GREAT EASTERN EXPRESS TYPE

interest. The dimensions are given in the table on the preceding page.

Further particulars of the decapod are as follows:—

Boiler—
Mean inside diameter ..... 5 ft. 3 in.
Length of barrel ..... 15 " 6¼ "
Length between tube plates ..... 15 " 10⅞ "
Longitudinal seams triple rivetted;
Circumferential seams double rivetted;
Joints telescopic;
Thickness of plates—
Barrel ..... ⅝ in.
Tube ..... ¾ "
Throat ..... ⅝ "
Back ..... ⅝ "
Wrapper ..... ⅝ in., in one piece
Tubes—Steel.
Number 395
External diameter ..... 1¾ in.
Thickness ..... No. 13 I.W.G.
Inside firebox—Copper plates, ⅝ in. thick;
Tube plate thickened to 1¼ in. at tubes;
Wrapper plates in one piece.
Length inside ..... 6 ft.
Width ..... 7 "
Bronze stays 1 in. diameter
Firebox shell—Width outside ..... 7 ft. 9½ in.
Length outside ..... 6 " 9½ "
Centres of outside cylinders ..... 6 " 8½ "
(Inside cylinder on centre line of engine.)
Distance between engine frames ..... 3 " 10 "
Wheel base (equally divided) ..... 19 " 8 "
Blast pipe—Macallan's "Variable," having a separate orifice for each cylinder, the total area being equal to that of a pipe 8¼ in diameter.
Diameter of blast pipe with cap on ..... 6⅝ in.
Brake—Westinghouse and hand.

Critics may possibly question the sufficiency of adhesion in the decapod. On this point a trial carried out early last year with one of the "Claud Hamilton" class is worthy of note. This engine (Fig. 11) has been authentically timed at eighty-four miles an hour; but in order to demonstrate its hauling capacity, forty loaded coal trucks and two 10-ton brakes were attached and hauled from Whitemoor to Stratford, a distance of eighty-eight miles. The total weight of this train was 710 tons. The train had to be started on a rising gradient and pulled round curves while sleet was falling. The actual tractive effort worked from an indicator diagram taken at starting was 17,542 pounds, which gives about 531.5 pounds per ton adhesion. The driving wheels did not slip.

A TYPICAL COTTON OIL MILL, REFINERY, LARD WORKS, AND SOAP WORKS

THE COTTON OIL INDUSTRY IN AMERICA

By D. A. Tompkins

CULTIVATING COTTON

IN the days before the Civil War in the United States, when the slogan of the South was "Cotton is King," when slavery and agriculture were supreme all over the South, cotton seed was a waste product, and in many parts a nuisance. In the ante-bellum days, the planters of Mississippi, Louisiana, Texas, and Arkansas, whenever it was possible, secured places on streams to build their cotton gin houses in order that the cotton seed (excepting that reserved for planting) could be discharged into the stream, and washed away. Where no such means of disposal were available, gin houses would be moved after two or three years, because of the offensiveness of the rotting seed. It was found to be easier and cheaper to move the gin house and its appliances than to move the great bulk of seed. Rotting seed makes good fertiliser, but in those districts the fertile alluvial soils did not need fertilisers. In some places where the seed was used as fertiliser, it had some commercial value for that purpose.

Aside from the use of a limited proportion of seed for planting, and a small amount, as first noted, as fertiliser, the first effort to get commercial values out of it was made at New Orleans in 1847, when a man, named Martin, built a mill to extract oil from the seed. One or two other mills were built before the Civil War. The oil from these mills probably went to France, where it was refined and sold as olive oil, the French population of New Orleans and its close commercial relations with France conducing to this opening of a market for the oil.

In 1868, General E. P. Alexander, an ex-confederate officer, built a cotton

LOADING COTTON AND COTTON OIL PRODUCTS AT NEW ORLEANS FOR EXPORT

seed oil mill at Columbia, South Carolina. This mill was operated several years, but was not profitable, because of the difficulty of getting cotton seed, and the machinery was eventually moved to a place in the Mississippi valley, where it was operated with success. From that time forward, the development of the cotton oil industry continued, slowly at first, but later with great rapidity. In the beginning of this development the oil was the principal

THE SALAD AND COOKING OIL DEPARTMENT OF A COTTON OIL MILL

product. Next to the oil, the meal was most important. It was extensively exported for feeding cattle and sheep, and also found a growing market as a fertiliser for cotton, tobacco, potatoes, and many other farm products. Later it came into still wider favour as a feed for beef and dairy cattle.

Up to about 1886, the chief commercial products of a cotton seed oil mill were oil, meal, and linters. These linters are a very short staple cotton which the ordinary cotton gin does not remove, but which is taken out in the oil mill by a special gin called a linting machine, or linter. Prior to 1886, the hulls from the seed were burned as fuel, to make steam to operate the mill and to cook the meats. As the ranges in Texas, however, became more and more encroached upon by settlers, the cattle men had to find some supplemental feed stuffs to help feed the cattle through the winter, and to fatten them for the market. Cotton seed meal was known to be an excellent feed for cattle and some other live stock, and experiments by the cattle men soon demonstrated that cotton seed hulls were as good for roughness as the meal was as a nitrogenous food.

The hull thus came rapidly in favour with cattle men, and then began to be sold at a price far exceeding its value as fuel. The knowledge and use of its value as a cattle feed came steadily from Texas eastward until now something of its value is well recognised over the entire American cotton territory. But it is only in Texas and other south-western States that the fullest value of the hull has become known. During the

SOAP MADE FROM COTTON SEED OIL

past winter, hulls sold in Texas as high as fourteen dollars a ton, while in the south-eastern States the prices have ranged from three to five dollars a ton.

The ordinary commercial value of cotton seed meal is based upon the use that may be made of it either as a feed-stuff or as a fertiliser. But it has, of late, become manifest that the economic value of this article is really a combination of the two uses, namely, a use, first, as a feed-stuff, and then a use of the resultant manure. Experience has shown that in this way, with proper skill, nearly double the value may be realised. Nothing but the inertia of old habits is holding back the general realisation of this fact.

Since the time of General Alexander's experiment at Columbia, the cotton oil industry has made great progress, and many additional uses and values in the various products have come to light. Methods of refining the oil for various uses have been studied out and operated with skill. It is now extensively used as salad oil, as cooking oil, as the basis of cooking compounds (containing cotton oil and beef suet), in packing sardines, as a lubricating oil, as illuminating oil in mines, in soap making, and for many other purposes.

The meal is used by manufacturers of commercial fertilisers to give the ammonia constituent, and, as previously noted, as a feed stuff for cattle and sheep. Some are said to have used it with great success as horse feed, claiming that its use gives a horse a very sleek and bright appearance.

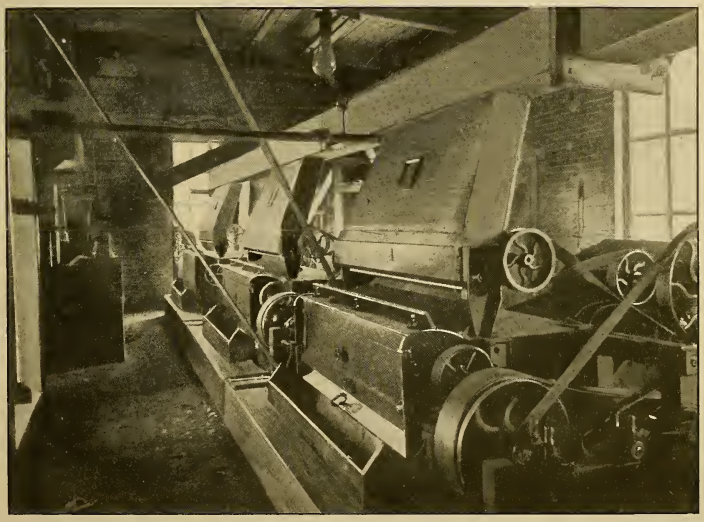
Both the oil and the meal are exported in enormous quantities. The oil goes to Italy and to France where, as already mentioned, it is refined and exported as olive oil. In many cases more or less olive oil is mixed with the refined cotton oil for shipping back to America. Much of the oil is exported also to Holland, where it is used in artificial butter making.

All cotton seed products are yet comparatively new, and even now their uses and values are not fully understood. The oil, when properly refined, is a

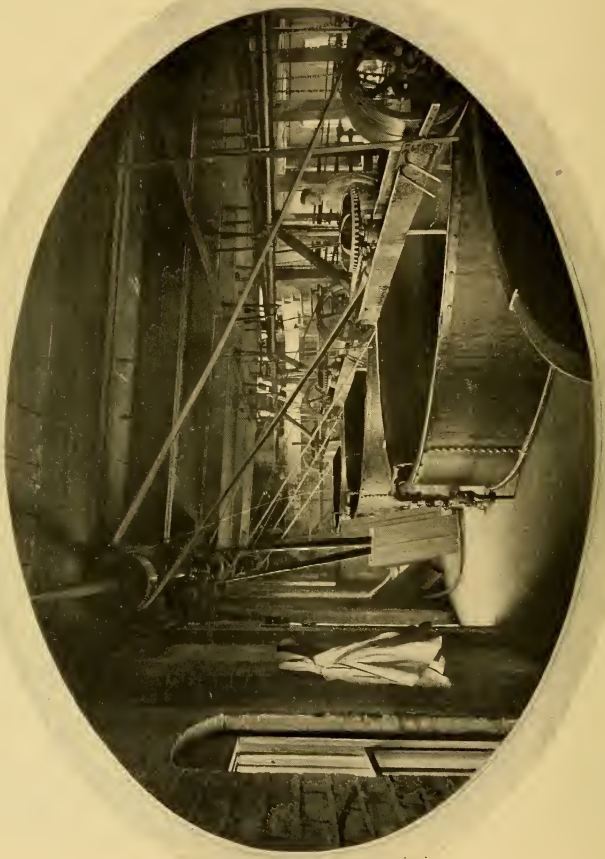
most excellent article for table use, and for cooking purposes. Food prepared with cotton oil, instead of with lard,—hog's fat in other words,—is recognised by the best physicians as very advantageous in cases of dyspepsia or other disorders of the stomach or bowels, and many physicians advise the use of cotton oil in such cases for cooking.

The oil is a pure vegetable product, and cannot be affected in any way by any animal disease, as is often the case with lard. The processes of manufacture and refining are clean and wholesome. A visit to a cotton oil mill or a cotton oil refinery is agreeable and appetising, while a visit to a slaughter house or lard refinery is quite the reverse. The workmen in the crude oil mills often catch the oil as it flows from the presses and use it in place of butter or gravy with their dinners. Many who cannot eat pastry shortened with hog's fat without having, afterwards, a feeling of oppression, can eat abundantly of pastry without subsequent discomfort, if shortened with cotton seed oil. As outlined in the writer's recent book on "Cotton and Cotton Oil," the process of manufacturing cotton oil underwent very little change until about 1880. From that time forward, great improvement has been made in machinery, such as improved hullers, improved linters, steel plate boxes in presses (requiring no hair mats), chilled rolls in place of muller stones, etc. The process, as now conducted in first-class mills, is about as follows:—

To begin with, the seeds are cleared of sand and other foreign substances, such as bolls, and pieces of wood, this being done by raising the seed by a cup elevator and discharging it into a revolving screen or reel. The reel is about five feet in diameter and fourteen feet long, and is usually enclosed with perforated metal, the perforations being small enough in the first half to hold the seed and let out the sand, while in the last half the perforations are large enough to let the seed go through while every-



IN THE LINTER ROOM OF A COTTON OIL MILL



THE COTTON OIL "LARD" DEPARTMENT

thing larger than a seed is carried over. Next the seed is carried to the linters and reginned for a part of the short lint. The linters are machines similar to saw gins, but so constructed as to gin closer in order to take off much of the short lint left on the seed by the gin. Following this, the seeds go to the huller, which cuts them to pieces. The huller is a machine having steel bars, called knives, set in a concave called the breast, and a cylinder carrying other knives running concentric in this concave breast. The seeds being fed into this machine are cut to pieces between the two sets of knives. From this machine the mass comes out as a mixture of hulls and meats. Then, in a reel, the meats are separated from the hulls. This reel is similar to the sand and boll reel except as to the perforations, which in this case let the meats through and carry the hulls over and out at the end, to be stored in a warehouse and eventually sold as cattle feed. They are sometimes shipped in bales.

The meats are taken to rolls which crush them, breaking the oil cells. These rolls are chilled, three to five high, thirty to sixty inches long and carried in housings. The meats pass down through the contacts of one pair after another and are thus completely crushed. From the rolls, the meats go into heaters, in which they are cooked. These heaters are steam jacketed kettles, having stirrers to keep the meats from baking to the sides and to make the cooking uniform.

From the heaters the meats are taken into the former, where cakes are formed and enclosed in cloth. This former makes a cake suitable to shove into the press. A cloth, generally camel's hair, is laid in the former, the cooked meats are filled in, the cloth is then folded over, and the cake, pressed by steam or power pressure, is then ready to go, cloth covered, into the press where the oil is extracted. The presses work at a pressure of about three to four thousand pounds per square inch. The cake remaining in the press is taken out, allowed to cool, and may then be cracked and ground into meal Before cracking or grinding, the cloth is of course

SOME OF THE COOKING HEATERS AND OIL PRESSES

COTTON OIL STORAGE TANKS

stripped off. It may not be uninteresting here to refer to the following table showing the growth and present magnitude of the cotton oil industry in the United States:—

TABLE SHOWING VALUE AND AMOUNT OF SEED CRUSHED, AND VALUE OF CRUDE MILL PRODUCTS, 1870 TO 1900

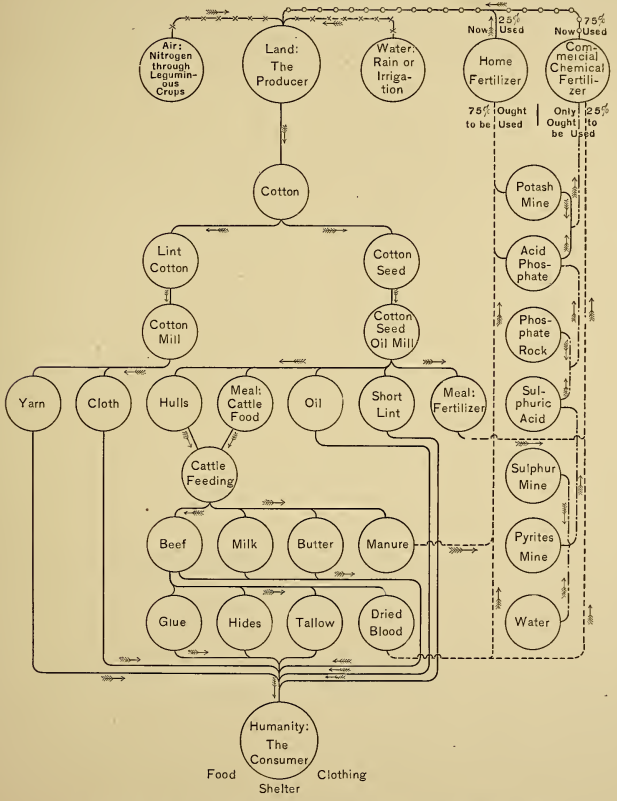
Year	No. of Mills	Tons of Seed	Value of Seed	Value of Products
1870----	26	80,000	$640,000	$1,500,000
1875----	35	150,000	1,500,000	2,900,000
1880----	45	280,000	2,800,000	5,100,000
1885----	80	550,000	5,500,000	9,600,000
1890----	119	1,000,000	12,000,000	23,800,000
1895----	250	1,800,000	21,600,000	33,000,000
1900----	400	1,900,000	23,800,000	35,000,000

This total value of cotton oil product ($35,000,000) is, however, far from the ultimate value that the South gets from the cotton oil industry. Most of the oil is not sold in the crude state, but is refined, and brings more money. The meal and hull go to feed dairy cattle, and to fatten beef cattle; and in these cases, additional values are procured.

The development of the cotton oil industry has in many ways had a marked influence on the economic conditions of Southern farm life. It has made the dairy business profitable by supplying cotton seed meal and cotton seed hulls as feed stuffs to supplement the other feed stuffs ordinarily derived from any Southern farm. The feed stuffs have been a necessity in Texas, and came just in time to make up for the curtailment of grass ranges brought about by the occupancy of the land by farming settlers. Indeed, throughout the South, it transpires that there are feed stuffs enough procurable from pastures or farms to abundantly supply cattle for dairy and beef purposes for eight or nine months in the year. The hindrance to the growth of a very large cattle business has been owing to the lack of some suitable feed stuff during the remaining three or four months. Cotton seed hulls and cotton seed meal exactly supply this deficiency, and in the seasons when they are wanted, namely, in the fall, the winter, and the early spring months. All that is said about the use of hulls and meal as a feed stuff for dairy

and beef cattle is equally applicable to the raising and fattening of sheep; but up to this time the application has not been made to sheep to any great extent.

Besides the direct money value of cotton seed products, it is clear that they make possible the development of a very large cattle business. The progress of this work is already very considerable. This cattle business, in turn, has a very great influence on the economical conduct of a farm, and especially in the production of cotton. As has been stated, cotton seed meal is a fine feed for cattle, and the cattle manure retains practically all the fertilising values in the meal. When the resulting manure is saved and used as a fertiliser, the full value as a manure is obtained in this way a second time, and it is also claimed that when cattle manure is used as a fertiliser on cotton, the cotton raised is stronger, longer, and finer of staple. Indeed, there is being rapidly developed a complete cycle of operations, commencing with the production of cotton,



A CYCLE OF PRODUCTION, CONSUMPTION, AND LAND RESTORATION

the passing to manipulation and crushing of the seed in the oil mill, the feeding of dairy cattle and beef cattle, and the return of the fertilising values to the soil, thus coming back to the production of cotton. Throughout this cycle, commercial products are being turned into the markets, for the various uses of humanity, and other values are being carried back into the cycle, to make up for those extracted. The diagram on page 53 illustrates this cycle.

The cotton seed oil industry is one of the main supports of the fertiliser industry in the South. Cotton seed meal furnishes one of the main ingredients in commercial fertilisers which are manufactured in such enormous quantities, and sold to planters and farmers, who produce cotton, tobacco, and sugar and various other crops.

The cotton oil industry further supplies a most excellent table oil, equal to most olive oil, and much cheaper; it furnishes oil for butterine, which can be made equal to the finest dairy butter, and far superior to "resurrected butter," which is sundry rancid butter melted and reworked and coloured and sold for dairy butter; it supplies material for the finest and sweetest soaps; it makes a lard compound which, for healthfulness, is superior to any hog lard, and incomparable with much of it; and it supplies meal and hulls, as supplemental feed stuff which is enabling all the South to indefinitely extend its areas of dairying and beef producing.

RAILWAY TRAINS ON FERRIES

THE CROSS-CHANNEL PASSAGE

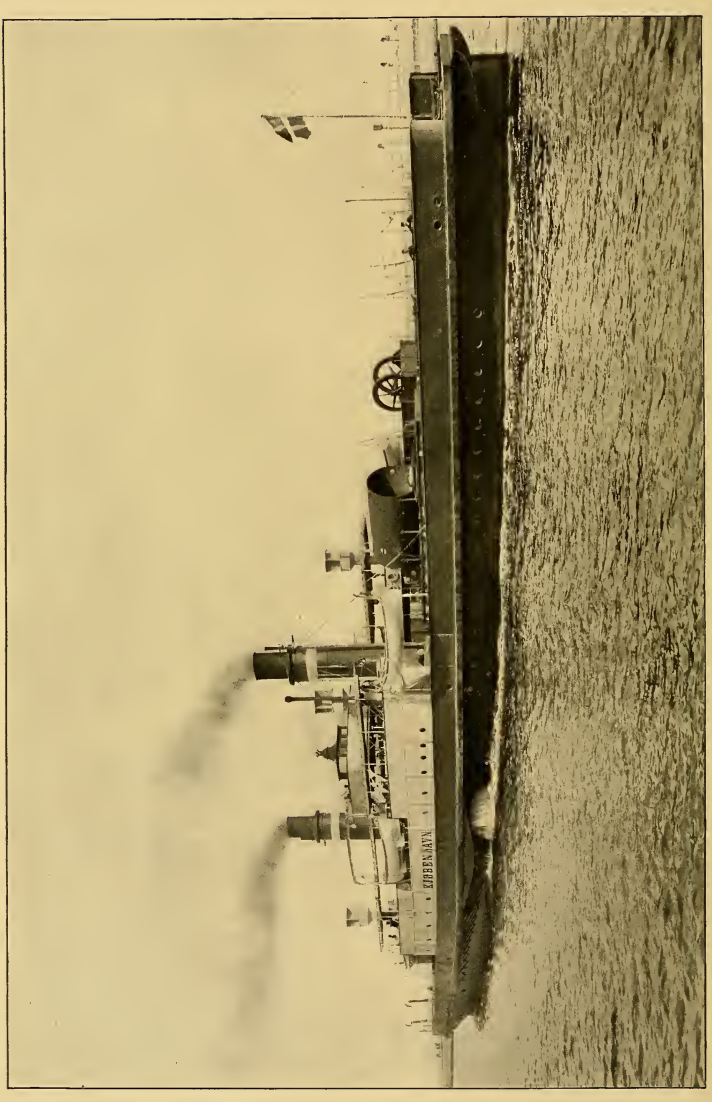
By Archibald S. Hurd

IS it too fanciful a dream that in time the traveller to Paris by a night train from one of the London termini of the South-Eastern & Chatham Railway, possibly after enjoying himself at a theatre and fortifying himself with supper, will take his place in a well-fitted and comfortably warmed "wagon de lits" and wake up in Paris the next morning, having passed from one capital to the other in a state of blissful unconsciousness? Is it possible that the visitor to the resorts in the south of France or to Italy or Switzerland will be able to travel through from Charing Cross to his destination without changing carriages, supping in London before starting and having breakfast in a saloon attached to the train at some French station, thus journeying with little fatigue or inconvenience?

Before such a forecast of the future is finally dismissed as impossible even within the lifetime of some of the present generation, those who would scoff at the suggestion should recall their memories of the conditions of travel in the past and compare them with their experiences to-day. Much has been accomplished in the past, and who shall say what is possible or impossible in the years that are to come, years in which the adaptation of electricity to commercial uses is sure to make great strides, when the steam turbine promises to revolutionise some types of ships, and when the train-ferry may supply a satisfactory solution of the problem here suggested? He would be rash indeed who would claim that present modes and rates of travelling represent finality, and that the future of mechanical and electrical development has nothing further to offer.

Only recently it was stated that the directors of the South-Eastern & Chatham Railway Company had been considering the use of the ferry for the cross-Channel passage, and in the course of a few weeks a turbine steamer will be making the passage from Dover to Calais well within the hour. On the other side of the "Silver Streak" the Northern Railway Company of France have accelerated their train service so that the passage from Calais to Paris is made at the rate of sixty miles an hour. Confirmation of the spirit of enterprise which is abroad may be found in the decision of the London & Brighton Company to order a turbine steamer for their Dieppe service.

It may at once be admitted, however, that disappointment is certain if too roseate views of the future be entertained, for it must be borne in mind that the conditions which govern the traffic from London to Paris are peculiar. It may be asked why, if the French company can take their trains at a speed of sixty miles an hour, the English company cannot do the same instead of being satisfied with a rate of forty-two miles an hour? The run to Paris from the coast is fairly flat, while the gradients in the journey through Kent are, in places, severe. In running from London the train is faced by five miles uphill from Rochester to Solehill, with a gradient varying of 1 in 100, while at portions of the line the curves are so severe that a high speed could be attained only at considerable risk. It is an interesting point whether the English traveller does not prefer safety to extreme speed; whether he is not satisfied with a moderate rate of progress by trains which run without variation to their scheduled



THE DANISH CAR-FERRY-BOAT "COPENHAGEN," RUNNING BETWEEN COPENHAGEN AND MALMÖ

times rather than a nominal high speed which is not realised. In the competition for speed there has been a tendency to claim in railway time tables speeds which have frequently not been attained, and it is probable that the business man with engagements to keep and the man of pleasure with arrangements depending upon his arrival prefers to be treated quite honestly, to start on his journey knowing that he will reach his destination at the appointed time. This would seem the most reasonable procedure and the one calculated to please all sections of the community, and this is what the South-Eastern & Chatham Railway Company hope to attain with the new express engines which are now being placed on their system.

On the other hand, can nothing be done to render the cross-Channel passage more pleasant? Here again the conditions which face the reformer are most difficult. The Channel narrows at Dover to a matter of twenty miles only, and consequently the volume of water which rushes through at that point is very great. There is a rise and fall off the Admiralty pier of from 15 to 20 feet, and occasionally even more, and the speed of the current varies from three to three and one-half miles an hour. One has only to stand on the new works of the national harbour at Dover and watch the current as it swishes round the staging to appreciate the danger attending any rash experiments in a seaway of this character. Those who have made the passage to Calais with a high wind on the beam will not need any further explanation of the difficulties which have to be faced in attempting to accelerate the journey.

Nevertheless, the company carrying the heaviest traffic in goods and passengers have not been content to stand still, and the South-Eastern & Chatham Company has passenger steamers which, under good conditions, now do the journey in less than an hour. It is not anticipated that the new turbine steamer will do better than this. This vessel, however, has one great advantage over the present type. In a paddle steamer the propulsive power is not constant, while in the turbine steamer it may be made so, thus affording higher speed possibilities with less vibration. At least this is the hope, and it may be that the absence of paddle boxes, which catch the seas, will conduce to a reduction of rolling, and that in itself will be an immense gain. The new boat will be in every way a comfortable ship, going with regularity from pierhead to pierhead within an hour.

But it is the anticipation of the use of the train ferry across the Channel which has most recently excited the popular imagination. Can this system be adapted to the Dover-Calais journey so that the passenger who takes his seat in London will have no occasion to leave it until he reaches Paris? The uninstructed are apt to rush to the conclusion that what has been done on the Forth before the construction of the Forth Bridge, what has been and is now being accomplished across some of the American lakes, and is being performed by the State railways of Denmark, cannot be impossible in the Channel. As has been already pointed out, however, the rise and fall of the water off Dover is very considerable, and that alone makes such a solution of the problem which the train ferry presents one of great difficulty.

The ferry requires at each end a rising and falling landing stage, which shall fit the steamer with exactness whatever the height of the tide, so that the cars can be run on and off. In none of the existing ferry systems have the designers had to provide for so great an up and down movement as would be necessary at Dover. Then, again, it has to be established that a ferry steamer carrying heavy cars laden with passengers and their luggage can cross the Channel without rolling so much as to endanger safety.

These and other questions cannot be airily dismissed. But, on the other hand, there is some evidence for guidance. In an article in CASSIER'S MAGAZINE, of April, 1898, there appeared an article on "Car Ferrying on the American Lakes." For some years goods traffic has been carried across

MAP OF DENMARK, ILLUSTRATING THE IMPORTANT PART WHICH TRAIN-FERRIES PLAY IN TRAFFIC DEVELOPMENT IN THAT COUNTRY

Lake Michigan on car ferries. This mode of transport has been found to be cheap and expeditious, since it avoids the frequent handling of commodities and enables them to be carried from Prestigo Harbour to South Chicago Harbour, a distance of 240 miles, without breaking bulk; and from pierhead to pierhead the journey is done in twenty-three to twenty-four hours, if the ferry steamer is loaded with twenty-eight full cars.

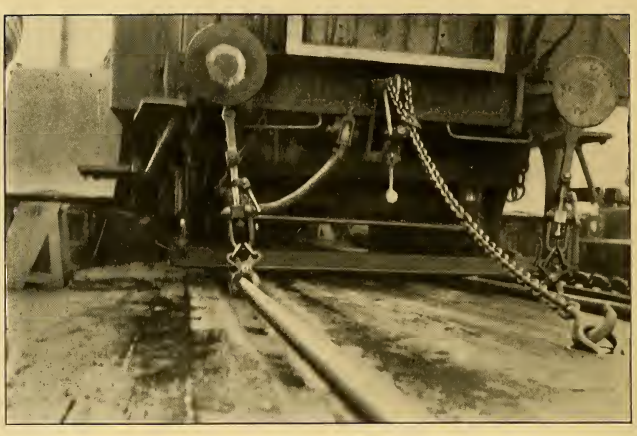
As may be readily understood, such an area of water, 335 miles long and from 50 to 88 broad, with low country around it, is not an unruffled mill pond,

and yet by ingenious arrangements and the use of a towing machine, two boats are towed in the wake of one steamer, the machine taking up the slack of the cable and releasing it as the strain is increased. In America such a form of towing machine is very generally adopted, and experience on Lake Michigan has shown that it overcomes the difficulties attending the haulage of several boats at a time. In fact, so complete has been the success of the car ferry on this, the third largest lake in the United States, that passengers are now taken across in the summer months between Ludington, Mich., and Manitowoc, Wis., the whole train, except the locomotive, being placed on the boat and transported over the water.

Possibly the country in which the ferry system (as may be seen from the map which accompanies this article) has been brought to the highest state of perfection is Denmark. To that country not long since Mr. John Avis, the Continental Passenger Superintendent of the South-Eastern & Chatham Railway, went on a tour of inspection to see how far the system would lend itself to adaptation in the Channel service. Of course, there are difficulties which would have to be surmounted; but if the will is there, there seems no reason why the system should not be tried for goods traffic, providing the saving in the dealing with freight would compensate for the heavy expense of building the ferries and providing the movable landing stages at each side. The whole problem resolves itself to the question whether it would pay.

It is probable that the saving which would be effected would be very great, for goods would be loaded up in the north of England, may be, and would run right through to the Continent without any of the heavy charges involved in removal to the steamer and then again from the steamer to the railway on the other side. On the other hand, the custom authorities on the Continent would have to be reckoned with, and at present French rolling stock is not suitable for use on the English system.

READY TO DISEMBARK



THE CARS ARE SECURED TO THE DECK BY RAIL CLAMPS AND CHAINS

These are minor points, and the main question is whether the cross-Channel passage is suitable for the use of the car ferry.

Two reasons have led to the general use of ferries in Denmark. One is the configuration of the country, which consists, for the most part, of a number of islands, and the other is the small travelling population which for years forbade the expenditure necessary to provide bridges even where these would be practicable. Consequently, the inventive genius of the Danes has been directed to the improvement of this mode of crossing the stretches of water which intersect the kingdom, and to-day Denmark possesses a ferry system which has proved not only a great convenience to the travelling public, but has greatly developed traffic.

At present there are seven connections by railway ferries, their sailing distances ranging up to nearly eighteen and one-half miles, while an additional one will be opened this autumn from Gedser to Wanemünde, a distance of twenty-six miles, opening up a new short route to Germany. For working the traffic the State railway department possesses six large and twelve small car boats, all of them paddle boats, with the exception of two of the small ones. The large ones are of 435 tons register and about 1600 indicated horse-power, and the others of 190 and 500, respectively. The average speed is 13 and 10½ knots.

The boats are thus described by Mr. P. Tegner, the ship inspector of the Danish Government Railway and Steamship Department:—In the design of the boats it has been the aim to observe, as far as possible, the same principle for both types, the main difference being that the larger type has two tracks on the deck, and the smaller one only one. The former can take about eighteen goods-trucks, the latter only six. A special point is made of the fact that the carriages can be shipped or landed as well over the after as over the fore end of the boats.

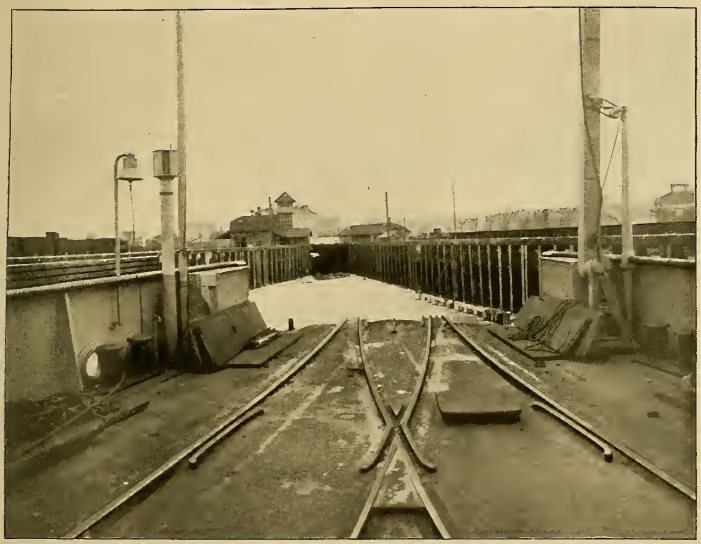
To secure the shipping and landing of the carriages, special berths have been built, made so that they fit exactly to the outer shape of the boats. The latter are built symmetrically in respect of the midship section, and the ends are formed by semi-circles and two straight, converging lines. The connection with the shore, made difficult by the variation of the tide, is effected by a lifting bridge about 65 feet long, counterpoised when empty, and so constructed that it

is able to yield and twist into a warped shape, following the movements of the boat when it heels over during the landing or shipping of the trucks. The bridge is lowered down upon brackets in the bow of the boat and secured to it by a pivot fitting into a corresponding hole in the bracket. The bridge is moved by hand-power, or, in a few installations, by electricity.

To sustain the heavy load of the trucks on the deck the rails are placed in channel irons direct on the iron deck; underneath, between the deck beams, heavy I-beams are placed, supported by stanchions.

The position of the two funnels, of engineer's station, companions, etc., is determined by the space which must necessarily be left free for the passage of the carriages on the ferries. For the same reason it has been necessary to place the captain's bridge above the carriages and between the funnels. On one boat this bridge is connected with a smaller bridge forward of the funnels on account of their hindering a free lookout. The newest boats are provided with electric light, mechanical ventilation, steam heat, and steam steering engine.

For the accommodation of first and second-class passengers there is at one end of the boat a large dining saloon, with pantry, ladies' and a gentlemen's separate saloons, with toilet room and lavatories attached; for third-class passengers there is at the other end a large saloon, with toilet room. The rest is turned into cabins for officers and crew and for the cooks' and stewards' department. The midship portion is occupied by the engine and boiler room. There are also a smoking-room, post office, chart room, and sundry cabins for the officers and for the train officials.



ENTERING ONE OF THE FERRY BERTHS

In order to keep navigation open during the winter, special ice breakers are in service. But the problem of making the ferryboats themselves ice-

breaking has been under consideration. On account of the small depth of water in nearly all the ferry berths it has been difficult to experiment. A new boat, however, has just been built at Elsinore for the Elsinore-Helsingborg service, by which it is hoped to establish a type, which, with increased depth of water in the ferry berths, may make the expensive plant of ice-breakers superfluous. This new boat is about equal in size to the existing smaller type. Its length is 179 feet, beam 43 feet, and draught 10 feet. It has a propeller at each end. It has one track capable of accommodating seven trucks. Two triple-expansion engines furnish power; the ordinary working steam pressure in the boilers, of which there are two, is 120 pounds per square inch; the calculated speed is 12 knots.

Another new type of boat is being built for the Gedser-Warnemünde route, which is to be half Danish, half Mecklenburg. Four boats will be necessary to maintain the traffic without interruption; two are to be Danish, the other two German. Mr. Tegner explains:— "All the experience gathered by thirty years' building and working on railway ferries has been brought to bear on the planning and fitting of these ferries, which we have reason to hope will turn out to our satisfaction. Only one new circumstance has had to be taken into account, viz., the heavy sea to be met with on this route. The size of the boats, however, will here be useful. Each country is building one paddle-wheel and one twin-screw boat. The paddle-wheeler has only one track of rails, and is constructed for the passenger traffic; the twin-screw boat has two tracks, and is intended principally for the goods traffic. Still, the two screw-boats, during ice periods, will be used for all the traffic, in order not to expose the paddle-wheelers to damage by ice. The dimensions of the two types are very nearly alike. The length will be about 280 feet, beam about 60 feet, and the draught, fully loaded, is for the paddle-boats about 12 feet, and for the screw-boats about 13 feet 5 inches. The indicated horse-power of the engine will be 2600. There will be four boilers, and the speed is to be about 14 knots. The ferries will be fitted with all modern comforts, and although it is the intention to carry all the passenger carriages across, a large portion of the space in the boats will be utilised for private cabins for passengers. In order to provide a large area for promenading, a light deck will be built above the carriages, affording room also for a smoking saloon, a ladies' saloon, and a chart room."

Without these ferries Mr. Tegner believes that the traffic in Denmark could not have developed to the remarkable extent that it has in the past thirty years. In only one instance are passenger carriages transported, the boats being built mainly for goods waggons and luggage vans, but the accommodation for passengers is excellent.

Those who look forward to the use of ferries across the English Channel will watch the development of this experiment with great interest, for between Gedser and Warnemünde the ferry will be open to the full current of the Baltic, with occasionally very heavy seas to be encountered.

There is no doubt that the car ferry system of transportation is still in its infancy. It has, however, been adopted across the Strait of Messina, the Nordsee Canal, in Holland; from Rugen Island to Stralsund, in Pomerania; while for the transport of goods it is increasingly used across the Hudson and other great rivers of the United States. It has also been installed to carry the passenger trains of the Siberian Railway across Lake Baikal, forty-two miles, a sheet of water which is far from being a mill-pond. In this instance the largest of the boats was built by Sir W. G. Armstrong, Whitworth & Co., Ltd., specially with a view to surmounting the difficulties of maintaining traffic in winter. The vessel was given an unusually strong hull. The lines are such as to offer the least resistance to the moving masses of ice at the sides, and the stem and stern, consisting of great steel castings, are intended to deal the ice a concentrated blow. Built of Siemens-

Martin steel, this type of boat was designed to stand the severest strains. So completely is it divided into water-tight compartments that it is calculated that if it were pierced in several places, its stability would not be endangered, while to add further to its strength it has a double bottom. When in use, as it was last summer, the cars are run over a hinged gangway on to the deck, where they are held in position by means of special appliances. The passengers can be accommodated on the decks above' where several private staterooms and a private saloon, in addition to large public saloons or waiting-rooms, are provided.

One noteworthy feature of the vessel is the arrangement of the propelling machinery. There are three sets of triple-expansion engines. Two of these drive twin propellers fitted, as usual, at the stern, while a third propeller is at the bow of the boat for the purpose of disturbing the water under the ice, so as to assist the heavy steel stem in breaking it up, to be pushed aside by the advancing vessel.

Before leaving this subject mention should be made of the car-ferry service across the Carguinez Strait, in California. The distance is only one mile, but there is an 8-knot current. The vessel used is 424 feet long, with a beam of 64 feet. It is propelled by two vertical engines, with 60-inch cylinders and 11-foot stroke, each driving a paddle-wheel, while four balanced rudders assist in manœuvring the ship, which can carry twenty-four passenger cars, or twice the number of goods waggons. The journey, including the operation of embarking and landing the train, is made in a quarter of an hour.

From the details which have been given it will be seen that the car-ferry system is being rapidly developed, and in face of the progress which is being made, and especially of its adaptation to the long and rough passage from Gedser to Warnemünde, who shall say that the fanciful picture with which this article began will not be realised, and that at some future time passengers who go to sleep as the express leaves Charing Cross will wake up in Paris without having been disturbed, if they be sound sleepers?

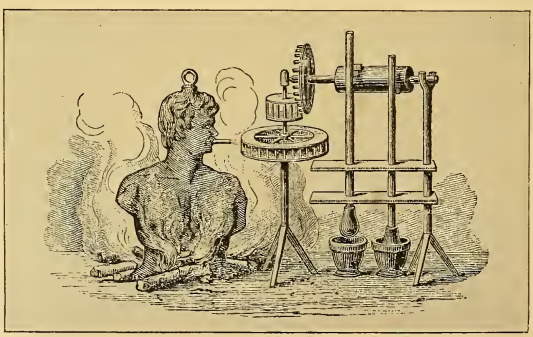
RECENT STEAM TURBINE APPLICATIONS

WITH DATA OF PERFORMANCES

By Hon. G. L. Parsons

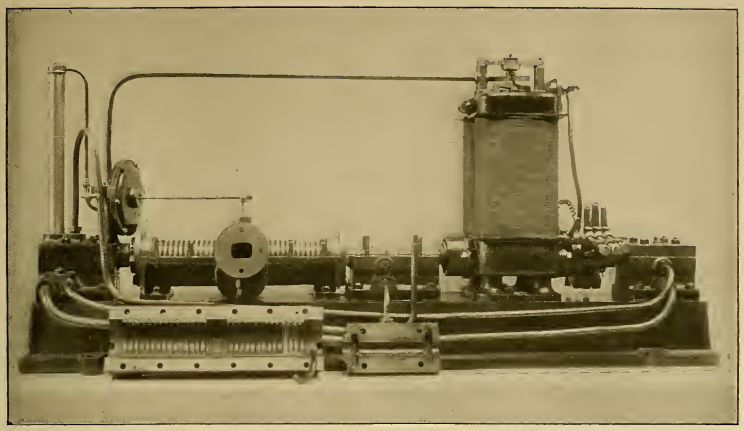
THE original Parsons steam turbine, brought out in 1884 and now in the South Kensington Museum, developed about 10 H. P. at a speed of 18,000 revolutions per minute. It was double-ended, the steam entering at the centre, and passing towards both ends of the shaft. Each half of the engine consisted of fifteen rings of blades, or turbine wheels, projecting out from the shaft, and nearly touching the concentric outer case. Between each row of these rotating blades there was a ring of fixed guide-blades projecting from the case, and nearly touching the shaft. Each set of this series of rings was like a parallel-flow water turbine, complete in itself, with this difference, that the steam, after doing its work on one set of blades, passed on, without losing its longitudinal velocity, through the guide-blades to the next set of moving blades, and so on to the end, gradually expanding, and falling in pressure until it reached the exhaust, allowance being made for the increasing volume of the steam by the slightly larger passage-way in each succeeding row of blades. The end pressure caused by the steam was balanced, as the two series of blades on each half of the shaft were similar, and the only force exerted by the steam was purely rotary.

Owing to the high speed of rotation, a certain amount of clearance had to be allowed between the rotating and the fixed parts of the turbine, so that the leakage of steam had a very bad effect on the economy; but when larger sizes were built the speed of rotation was diminished, and at the same time the clearance losses were much smaller in proportion. By 1888 an aggregate of 4000 H. P. of turbines was at work, including several of 120 H. P., though none of them were of the condensing type.



AN EARLY FORM OF STEAM TURBINE. BRANCA'S ENGINE, OF 1629

According to a paper recently pre-



THE ORIGINAL PARSONS TURBINE, BUILT IN 1884, NOW AT THE SOUTH KENSINGTON MUSEUM, LONDON

sented by the writer before the Cleveland Institute of Engineers, tracing the development of the steam turbine, the radial-flow type was introduced in 1889. This consisted of a series of fixed annular discs with rings of blades, between which another series of discs, keyed to a shaft, rotated. The guide-blades were secured to the faces of the stationary discs, and nearly touched the rotating disc, while the moving blades nearly touched the fixed disc. The steam passed outwards through the successive rings of blades, then inwards along the back of the first moving disc, and again outwards through the blades of the second moving disc, and so on, until it ultimately reached the exhaust. In 1892 this type was first tried condensing, an engine developing about 150 H. P. being coupled to a 100 KW alternator, running at 4000 revolutions per minute. In this, with 100 pounds of steam, slightly superheated, and a vacuum of 28″ mercury, the consumption was 27 pounds per KW-hour, which is equivalent to 16 pounds of steam per I. H. P.-hour.

About two years later the parallel-flow type of turbine was again adopted, with considerable modifications. The turbine was made single-ended, with the steam passing in one direction, the second set of turbines being replaced by rotating dummy pistons, by which the end pressure of the steam along the shaft was balanced.

Grooves are turned in these pistons into which the corresponding fixed collars of the cylinders can project, and, being almost in contact, prevent any serious leakage of steam past the pistons, the amount of clearance being regulated by the thrust bearing at the end of the turbine shaft. The bearings consist of a brass bush surrounded by three concentric tubes, separated from one another by a thin film of oil, which damps all vibration. Also owing to the very small pressure on the bearings at all loads, the wear is practically nil.

The steam is admitted to the turbine in a series of gusts, regulated by the opening and closing of a double-beat valve, which, in its turn, is controlled by a steam relay worked by the governor. As the load on the engine increases the governor increases the length of the gusts of steam, until at full load they are practically continuous. The periodic motion is given to the steam relay valve by a series of levers worked by a cam driven by a worm-wheel off the turbine spindle, the gov-

ernor simply altering the mean position of the relay valve, and thus lengthening or shortening the gusts of steam.

The governor can be either of the mechanical type, which keeps the speed constant, or of the electrical solenoid type, which maintains a constant voltage at the terminals of the dynamo.

The worm-wheel mentioned previously also works a small oil pump, by which the oil is supplied under pressure to all the bearings, being then returned to a tank to be used over again, resulting in a very great saving of oil, as compared with ordinary reciprocating engines. Since the cylinder itself requires no lubrication, the exhaust steam is entirely free from oil, and the condensed water can be used direct for feeding the boilers.

Various improvements were also made in the design and construction of the vanes, which resulted in considerably greater economy of steam. About this time several turbines of the non-condensing type were put down in the Manchester Square Station of the Metropolitan Electric Supply Company, of London, where an injunction had been obtained against the company on account of the vibration caused by the reciprocating engines already installed. These turbo alternators were of 350 KW capacity, and gave complete satisfaction. Since that date the size of turbines has gradually increased, units of 500 KW being put down in Newcastle, Scarborough, Cambridge, London, and other places.

In 1900 two alternators, each of 1250 KW capacity, were made for the city of Elberfeld, Germany. The turbines were of the tandem type, consisting of high and low-pressure cylinders, and ran at 1500 revolutions per minute. The dynamos were four-pole, and supplied single-phase current at 4000 volts and 50 periods. The steam consumption with slight superheat was 18.8 pounds per KW-hour at full load, or 11.9 pounds per I. H. P., including the power required to drive the air pumps. These dynamos run perfectly in parallel with the 1500 H. P. Sulzer engines, which are coupled to 1000 KW Brown Boveri alternators, running at 93 revolutions per minute. In fact, the turbines steady the reciprocating engines, even when the latter are running on traction load.

During the last few years new designs have been brought out, in which the steam consumption has been further reduced, giving, especially in the larger sizes, some very remarkable results. A few examples of the amount of steam used by various sizes of turbine are given below:—

50 KW STEAM ALTERNATOR FOR THE BLACKPOOL CORPORATION

Pressure of Steam above Atmosphere at Stop Valve	Superheat at Stop Valve	Vacuum in the Turbine Cylinder. Bar. = 3.	Revs. per minute	Load	Steam Used	
Lbs. per sq. inch	F.°	Inches of Mercury		K Ws	Lbs. per hour	Lbs. per K W hour
126	0	28.0	5044	52.7	1480	28 0
132	0	28.5	4280	0	320	----

TWO 100 KW CONTINUOUS-CURRENT TURBO DYNAMOS, FOR WEST BROMWICH ELECTRIC LIGHTING STATION

Pressure of Steam above Atmosphere at Stop Valve	Superheat at Stop Valve	Vacuum in the Turbine Cylinder. Bar. = 30".	Revs. per minute	Load	Steam Used	
Lbs. per sq. inch	F.°	Inches of Mercury		K Ws	Lbs. per hour	Lbs. per K W hour
129	54	27.8	3500	123	3144	25.5
134	64	27.8	3520	122	2913	23.8

35 KW THREE PHASE ALTERNATOR (3,300 VOLTS), FOR FINDLAY, DURHAM & BRODIE

Pressure of Steam above Atmosphere at Stop Valve	Superheat at Stop Valve	Vacuum in the Turbine Cylinder. Bar. = 30"	Revs. per minute	Load	Steam Used	
Lbs. per sq. inch	F.°	Inches of Mercury		K Ws	Lbs. per hour	Lbs. per K W hour
140.3	99.0	27.15	3600	138.3	3152	22 8
130.4	81.0	27.3	3600	66.9	1845	27.6

200 KW CONTINUOUS CURRENT MACHINE, FOR WEST BROMWICH

Pressure of Steam above Atmosphere at Stop Valve	Superheat at Stop Valve	Vacuum in the Turbine Cylinder. Bar. = 30"	Revs. per minute	Load	Steam Used	
Lbs. per sq. inch	F.°	Inches of Mercury		K Ws	Lbs. per hour	Lbs. per KW hour
134	76	27.71	3000	204.4	4260.0	20.8

300 KW THREE PHASE ALTERNATOR, FOR DE BEERS MINES, SOUTH AFRICA

Pressure of Steam above Atmosphere at Stop Valve	Superheat at Stop Valve	Vacuum in the Turbine Cylinder. Bar. = 30"	Revs. per minute	Load	Steam Used	
Lbs. per sq. inch	F.°	Inches of Mercury		K Ws	Lbs. per hour	Lbs. per K W hour
150.0	53.3	27.8	3000	312.1	6260	20.06
153.0	50.0	27.8	3000	231.8	4960	21.45
150.5	40.2	27.9	3000	154.5	3070	23.75

350 KW CONTINUOUS CURRENT MACHINE, TANDEM DYNAMOS, FOR THE PENNSYLVANIA SALT CO.

Pressure of Steam above Atmosphere at Stop Valve	Superheat at Stop Valve	Vacuum in the Turbine Cylinder. Bar. = 30"	Revs. per minute	Load	Steam Used	
Lbs. per sq. inch	F.°	Inches of Mercury		K Ws	Lbs. per hour	Lbs. per K W hour
150	71.3	27.82	3360	359.5	7423	20.64
152	65.7	28 27	3151	185.5	4346	23.44
140.2	92.3	17.4	3430	353.5	9030	25.54
143.4	82.5	17.4	3255	177.2	5715	32.26

500 KW SINGLE PHASE ALTERNATOR (2,200 VOLTS) FOR HASTINGS

Pressure of Steam above Atmosphere at Stop Valve	Superheat at Stop Valve	Vacuum in the Turbine Cylinder. Bar. = 30"	Revs. per minute	Load	Steam Used	
Lbs. per sq. inch	F.°	Inches of Mercury		K Ws	Lbs. per hour	Lbs. per K W hour
145	93	27.4	3000	501.9	9776	19.47
148	90	28.1	3000	255.1	5612	22.00

Last year, two large continuous-current plants were constructed for the Newcastle and District Electric Lighting Company. Each set consisted of a 1750 H. P. turbine, running at 1800 revolutions per minute, coupled to two 500-volt, four-pole dynamos, each of 500 KW normal capacity. The engine is fitted with the electrical solenoid type of governor, which maintains the voltage constant at all loads within 2 per cent. In order to provide sparkless commutation with change of load, the position of the brush rockers is controlled automatically. A pipe is led from the high-pressure part of the turbine to the under side of a piston, working in a small cylinder against a spring. As the lead to be given to the brushes and the mean pressure in the turbine both vary in proportion to the load on the engine, the piston in the small cylinder moves up and down against the spring, and thus instantly brings the brushes to the right position. On being tested at Heaton Works at 10 per cent. under full load, the following results were obtained:—

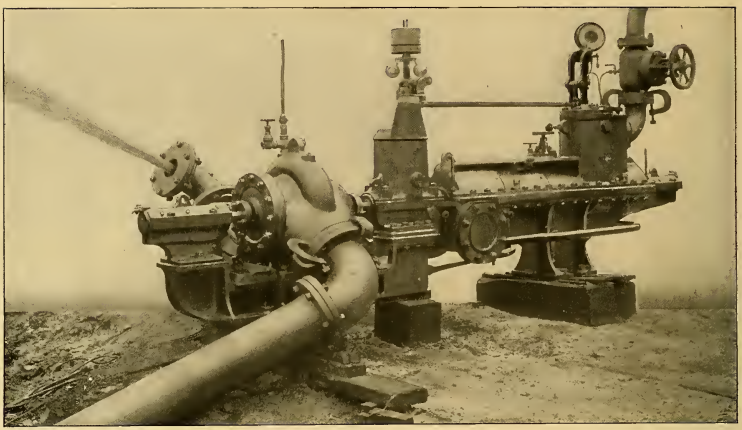
Speed.	Steam Pressure	Superheat	K W	Water per hour, Lbs	Water per K. W. hour, Lbs	Vacuum, Inches of Mercury
1,710 R.M.	145	237° F.	897	15,922	17.73	26.5

With a vacuum of 27 inches and 240° F. superheat, the consumption would have been about 17 pounds per KW-hour.

During the autumn two large continuous-current plants of 1800 KW each have been supplied to the Corporation of Manchester. The engine, of about 3500 H. P., is supplied with steam at 130 pounds pressure, and runs at about 1000 revolutions per minute. It is coupled direct to two dynamos, each of 900 KW normal capacity, and capable of an overload of 10 per cent. Each dynamo has six poles, and generates at a pressure of 450 volts. A steam consumption of 20 pounds per KW-hour without superheat has been guaranteed, and is expected to be easily attained.

The size of turbines for land power purposes seems to be steadily growing, until in a few years single plants of 10,000 KW will be comparatively common. In the large sizes the space required is one-half or even one-third of that taken by the present types of vertical engine, while the engine rooms can be built much lower, and do not need such powerful cranes, owing to the light weight of the parts. The number of men employed in a turbine-driven station is much smaller, three men being required for each vertical marine type of engine, while one man can easily run two turbines, the oiling being entirely automatic. Since no lubrication is required in the interior of the cylinder, the use of superheated steam causes none of the difficulties which are met with in the case of reciprocating engines.

Tests have been made at various times



A CENTRIFUGAL PUMP AND STEAM TURBINE COMBINATION

to see whether the consumption of steam increases with the age of the plant, and in all cases the high initial economy has been fully maintained. Turbines are now being used for all sorts of electrical work. Many central stations use nothing else for lighting their towns. In others, again, they generate the current required to drive the electric trams, or supply power for various mills and factories in their district.

TURBO FANS

Lately the turbine has been adapted to the driving of fans for ventilating collieries. One has been running over five years at a colliery near Newcastle, often for the whole twelve months without a stop, and has given every satisfaction. Its maximum output is 120,000 cubic feet of air at 2¼-inch water gauge, at a speed of 2000 revolutions per minute. This plant may practically be said to run itself, being locked up in a wooden shed, into which the attendant goes about twice or thrice a day.

Another turbo fan is running near Bolton, Lancashire, at a speed of 3000 revolutions per minute; it gives 80,000 cubic feet at 6-inch water gauge. The fan is generally of the screw type, and of small diameter, working in a cone. Owing to its light weight and small size, the cost of buildings and foundations is very much less than in the case of large diameter mining fans of the usual types. Turbo fans have also been used for forced draught and for hot furnace gases, running continuously for many months with practically no attention.

TURBO PUMPS

Two sets of pumps have lately been supplied to the Agent-General for New South Wales for the Sydney Water Works. The first set consist of a steam turbine coupled to three centrifugal pumps of special high speed type, each single pump being capable of raising one and one-half million gallons, or a total of four and one-half million gallons of water per twenty-four hours, to a height of 240 feet. When these pumps are coupled in series they are capable of raising one and one-half million gallons per day to a height of 720 feet. The turbine here has given a consumption of only 28 pounds steam per W. P. hour at full load, showing a pump efficiency of 55 per cent. The economical working of this set of pumps may be better appreciated when it is stated that the useful power in water delivered is equal to about 34 per cent. of the power

obtainable from a theoretically perfect steam engine using the same pressure and temperature limits.

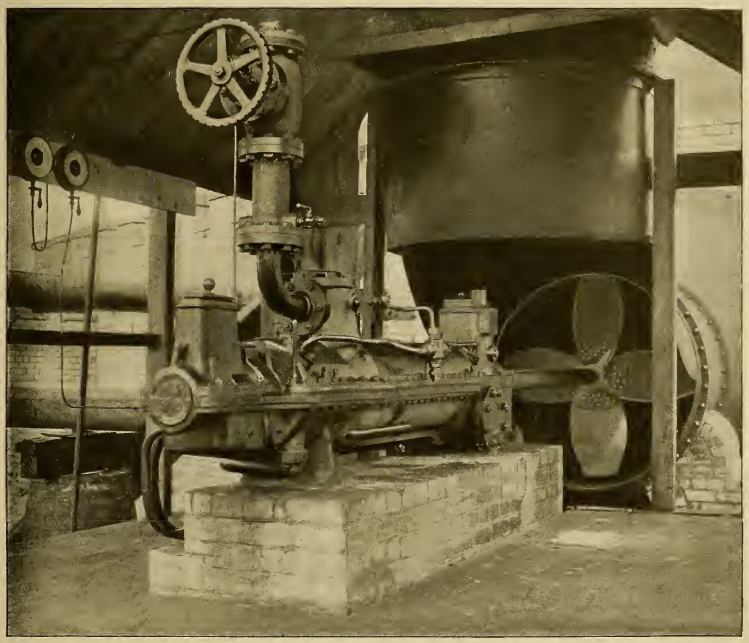
The second set comprises a steam turbine, driving three pumps of the so-called Augmentor type, capable of raising ten million gallons per day to a height of 80 feet when in parallel, and three and one-third million gallons to a height of 240 feet when in series.

Each set is complete with its own surface condenser and a pair of air pumps driven by worm gearing off the main shaft. This condenser forms a byepass to the main suction pipe, a butterfly valve being provided, by means of which the flow of water through the condenser may be regulated. Steam is supplied to the turbines from Stirling boilers at a pressure of 150 pounds per square inch.

An interesting feature of this contract was the very short delivery, for the order was only placed on September 11, 1902, and the whole of the work, including the detailed drawings and patterns, was finished in sixteen weeks.

TURBO BLOWING ENGINES AND AIR COMPRESSORS

An important discovery has lately been made in the form of the blades which enables the turbine principle to be used for compressing air, an ordinary steam turbine or other high-speed motor being coupled direct to the air turbine. The air turbine is very similar to the steam turbine. It consists, as usual, of alternate rows of moving blades and guide-blades, and is driven at a high speed, each row of blades increasing the pressure and giving a perfectly steady blast. One plant, installed for a lead



A 100 H. P. TURBO-FAN AT CLARA VALE COLLIERY, NEWCASTLE-ON-TYNE, ENGLAND

works on the Tyne, consisted of an electric motor driving an air turbine, which supplied 3500 cubic feet of air per minute at 4-inch mercury pressure. When this plant was set to work, an increase of 30 per cent. was noticed in the output of the furnace, due apparently to the steadiness of the blast.

A blowing engine is now running at the Farnley Iron Works, near Leeds. It consists of a steam turbine running at 5200 revolutions per minute, driving an air turbine. The output is 11,300 cubic feet free air per minute at 3 pounds pressure. The power in the useful output of air was found to be 61 per cent. of that theoretically obtainable from the same amount of steam used in a theoretically perfect engine, between the same limits of pressure and temperature. This leads to the fact that both the steam turbine and the air turbine have an actual efficiency of about 78 per cent.

In all these plants no air valves are required, as the moving vanes maintain the pressure of the blast, so that as in the case of the ordinary steam turbine the repairs are practically nil, and the efficiency of the plant will be maintained indefinitely. When an increased pressure is required to clear the furnace the speed of the steam turbine can be increased by opening a bye-pass and admitting high-pressure steam to the low-pressure part of the cylinder, and the pressure given by the air turbine can be thus increased in proportion.

A high-pressure, two-stage air compressor on the turbine principle is now being constructed for the George Goch Mine, at Johannesburg. It is fitted with condenser, pumps, and intermediate cooler, and is designed for an output of 4000 cubic feet of free air per minute at 80 pounds pressure.

THE MARINE STEAM TURBINE

In January, 1894, a syndicate was formed for the purpose of applying the steam turbine to the propulsion of ships. The *Turbinia* was the first vessel to be constructed, her dimensions being, length, 100 feet; beam, 9 feet; draught of hull 3 feet; and displacement, 44 tons. The engines consisted of three turbines, high-pressure, intermediate, and low, on three separate shafts, each fitted with three propellers, the low-pressure turbine and also the reversing turbine being coupled to the central shaft. The boiler was of the express small-tube type, without feed-water heater. With a maximum of 2300 H. P. a speed of 34½ knots was obtained. At a speed of 31 knots the total consumption of steam was 14½ pounds per H. P. per hour.

In 1898-9 the torpedo-boat destroyer *Viper* was constructed for the Admiralty. Her dimensions were 210 feet length by 21 feet beam, and her displacement was 370 tons. On trial, she obtained a mean speed of 36.87 knots, while a speed of 36.58 knots was kept up during a one-hour full power run, the H. P. developed being about 12,300.

In 1901 the first mercantile ship, the *King Edward*, was fitted with turbines. The principal dimensions were, length, 250 feet; beam, 30 feet; depth, 17 feet 9 inches. With a maximum of 3500 H. P. a speed of 20.48 knots was attained.

The *King Edward* ran on the Clyde during the whole summer, averaging 18 knots. The following summer a second ship of slightly larger dimensions (270 feet by 32 feet by 18 feet 9 inches) was built. Her speed on the measured mile was 21.63 knots.

At present the *Velox* torpedo-boat destroyer is making her trials, while another destroyer, the *Eden*, and a third-class cruiser, the *Amethyst*, are now being built also for the British Government. Several private yachts have been engined with turbines, including the *Tarantula*, of 25½ knots. A few months ago two cross-channel steamers, of 21 knots each, were ordered. One for the London, Brighton & South Coast Railway, for the Newhaven Dieppe route, is to be ready in May. Her dimensions are 280 feet by 34 feet beam by 22 feet depth. The other boat was ordered by the South-Eastern & Chatham Railway Company, for the Dover-Calais route her dimensions being 310 feet long, 40 feet beam, and 25 feet height to the promenade deck.

Current Topics

In his recent inaugural address at the City and Guilds Central Technical College, at London, Dr. Alexander B. W. Kennedy took consulting engineers and their work for his topic. One of the things discussed by him was the business aspect of engineering,—the financial problems which the engineer had to solve. The main duty of a consulting engineer, the sort of thing he spends his time on, he remarked, is the formulation of what one may call "schemes." A corporation wants a water supply or a gas works, or a company wants a big manufactory, a railway, a bridge, or a design may be required for a tramway or other power house, or for an electrical transmission scheme. The engineer in such a case has not himself to design machinery, nor generally to design the details of anything, although he may have to design a general scheme of very great complication. His real work is to develop such a scheme in general outline; and almost the first scheme he has to consider, beyond and along with the actual engineering part of the work, is a financial one. He finds himself face to face at once with the question of cost; indeed, one of the most essential parts of an engineer's work is the consideration of what a thing will cost, and whether it will pay to carry out. He may be fortunate enough to receive instructions to carry out certain work entirely independently of what it is going to cost; but in that case it is desirable to have this stated in writing beforehand, so as to prevent any question being raised afterwards. Generally, however, the matter is put to the engineer in this way:—"Tell us first whether it will pay to carry out so and so, and, if so, how best to carry it out."

The question as to whether a thing will pay is influenced by a great many conditions. It is influenced first by the immediate cost, which is not a very serious matter to arrive at by estimating. A much more difficult question is to arrive at the conclusion whether certain variations, certain improvements, or certain alterations, which will cost money, will really yield a profit if carried out; and here come in certain pitfalls. There may be two ways of doing a thing, of which one may cost £20,000 more than the other, and the one which costs £20,000 more may be the "better" way. The engineer's business, however, is not necessarily to follow the better way; his first business is to find out whether that way is going to pay;

and if that additional £20,000 is going to save only £500 a year, he had better not ask his directors to spend the money. This is a question which crops up continually. For example, in the case of a power house there may be a question of using condensing or non-condensing engines. You know that if you use condensing engines you may save 15 per cent. or thereabouts in fuel, and, therefore, condensation is "better" than non-condensation. But one must look at the matter not only from the engineering, but also from the financial point of view. Dr. Kennedy mentioned a case in which the actual cost of condensation,—which could be carried out very well,—was something like £30,000 for a certain power house. If that £30,000 is going to entail capital charges of £1500 a year, the question is whether the 15 or 20 per cent. of the coal bill is or is not worth that amount. It may be "better," but it may not be in the least worth while doing unless it is followed by a true and actual saving. Dr. Kennedy put down in a large power house some years ago plant for superheating the steam, which worked most successfully and without any trouble whatever. When he came to put down another station in the same city he naturally inclined to do the same thing again. First, however, he decided to run the first station week about with the superheating and without it for a while. In this way he found that the difference in fuel amounted to about 6 or 7 per cent. of the coal used. The coal cost 7s. a ton, and it was only a question of arithmetic to see whether he was at liberty to put superheaters in the new station. The result was that they were not put in Questions like this are not, of course, matters that one can say anything of in general; they must always depend on a particular place and particular circumstances. If an engineer can get coal at seven shillings a ton, there are many things not worth while doing which would be desirable or essential when his coal costs him twenty-five shillings a ton or thereabouts. Every case has to be judged on its own merits and conditions.

BEARING further on this general subject, Dr. Kennedy went on to say that there is sometimes a great cry about transmission of power from coal fields; it is said that we ought to be able to utilise the resources of our coal fields on the spot and transmit electric energy, say, 200 miles away. It is a very pretty idea, and there is no difficulty in carrying it out; but it is, unfortunately, entirely a question of cost. One must not be led away by a scheme just because it sounds attractive; the matter is really one only of money. A similar thing, also very much talked about, is the utilisation of water-power, and this also is really a financial matter, in which every case has to be judged on its own particular merits. The actual capital expenditure for any such scheme is always very large, and is also very nearly independent of the number of hours per day during which the power can be utilised; that is to say, very nearly independent of the load factor,—the capital charges are as great if the power is only to be used for six hours per day as if it were utilised continually day and night. If the engineer has to work out an arrangement of this kind which can be worked for only eight hours a day, he will almost certainly find that the capital expenditure is the same as if the plant were to be worked three times as long, and, therefore, the capital charges will be enormous in proportion. All the great water-power work which has been a success has been so because it has been supplied to works where the energy could be utilised during nearly all the twenty-four hours of the day, and the capital charges could be distributed accordingly.

IN a speech recently before the House of Commons, dealing with the education of naval officers, Mr. Arnold Foster quoted a distinguished naval officer in the lines below, which admirably present the naval engineer's claim to appreciation. "Everything in the modern fleet," so he said, "is done by machinery, be it steam, hydraulic, com-

pressed air, or electrical, to which will probably be added in the near future explosive oil and liquid air. Not only are the ships propelled solely by machinery, but they are steered by machinery. Their principal arms,—gun and torpedo,—are worked by machinery. They are lighted by machinery; the water used by those on board for drinking, cooking, and washing is produced by machinery; messages which were formerly transmitted by voice-pipe now go by telephone. The orders which the admiral wishes to give to the fleet could formerly be made only by flags in the day and lamps at night; they are now made by electricity,—that is, wireless telegraphy and electric flashing lamps. Orders which were formerly written out by hand are now produced by the typewriter or by the printing machine. Formerly the admiral visited another ship in his pulling barge; now he goes in a steamboat. The anchor, formerly hove up by hand, is now worked by an engine. The live bullocks which were formerly taken to sea are now replaced by frozen carcasses, maintained in that condition by machinery. If a fire breaks out in the ship, the steam pumps drown it; if the ship springs a leak, steam pumps keep down the water. The very air that those on board between decks breathe is provided by a fan driven by machinery." Lord Goshen has, indeed, aptly described the modern warship as "a fiendish complication of machinery."

With reference to the early use of gunpowder and firearms, long before the popularly accepted, but erroneous, date of gunpowder discovery, General Joseph Wheeler, U. S. A., in a lecture a short time ago before the Franklin Institute, remarked that in many localities in China and India the soil is impregnated with nitre, and the probable discovery of gunpowder there, many centuries before the Christian era, may be explained in this way:—All cooking at that time was by wood fires, and the people lived in tents and huts with earth or their floors. Countless fires made of wood upon ground strongly impregnated with nitre must have existed every day, and when such fires were extinguished a portion of the wood must have been converted into charcoal, some of which would, of necessity, become mixed with the nitre in the soil. By this means two of the most active ingredients of powder were brought together, and it is very natural that when another fire was kindled on the same spot a flash might follow. This would lead to investigation, and then the manufacture of gunpowder was conceived. Whether this be true or not, there is abundant evidence that the origin of gunpowder and artillery goes far back in the dim ages of the past. The Hindoo code, compiled long before the Christian era, prohibited the making of war with cannon and guns or any kind of firearms. Quintus Curtius informs us that Alexander the Great met with fire weapons in Asia, and Philostratus says that Alexander's conquests were arrested by the use of gunpowder. It is also written that those wise men who lived in cities on the Ganges "overthrew their enemies with tempests and thunderbolts shot from the walls." Julius Africanus mentions shooting powder in the year 275. It was used in the siege of Constantinople in 668; by the Arabs in 690; at Thessalonica in 904; at the siege of Belgrade, 1073; by the Greeks in naval battles in 1098; by the Arabs against the Iberians in 1147; and at Toulouse in 1218. It appears to have been generally known throughout civilised Europe as early as 1300, and soon thereafter it made its way into England, where it was manufactured during the reign of Elizabeth, and we learn that a few arms were possessed by the English in 1310, and that they were used at the battle of Crecy in 1346.

Mr. John A. Brashear, whose fame as a maker of astronomical and philosophical instruments is world-wide, in conversation some time ago referred to the extreme delicacy of a pair of scales at the International Bureau of Standards at Breuteil, near Paris, in a

manner which it may be interesting to recall here. The scales in question were in a vacuum,—within a heavy glass case,—and the construction of the whole outfit was such that the weights on the scale pans could be handled by means

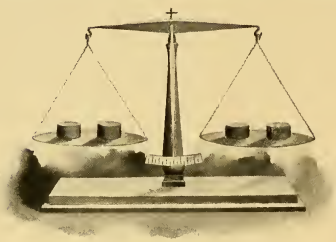


FIG. 1.

of levers and packed rods, with the operator so far away that the heat of his body could not affect the accuracy of the observations. The divided arc on the scales and the place of the indicator on it were read by means of a telescope. When two kilogramme weights were placed side by side on either scale pan, as represented in Fig. 1, above, the indicator, after quite an interval, would come to rest at zero; but, and this is the remarkable circumstance, when the position of the weights on

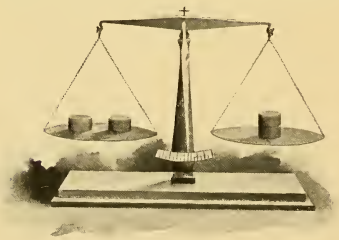


FIG. 2.

one pan was changed, as shown in Fig. 2, the left-hand pan, after a considerable period of time, would finally settle down as the heavier one, with the indicator away from zero, as indicated, the explanation being that the upper one of the weights in the right-hand pan was further away from the centre of the earth, or attracting mass, than when on the same plane with its companion weights. This may sound like a Münchausenism; but, nevertheless, it is literally true, and, as Mr. Brashear remarked, can be corroborated by Dr. Michelson or Mendenhall or Stratton. Of course, it means the most perfect mechanism in the scales and absolutely exact weight in the several kilogrammes used.

At a recent meeting of the American Institute of Electrical Engineers Mr. W. J. Hammer delivered a remarkably interesting lecture on a diversity of subjects, such as radium, selenium cells, treatment of lupus by ultra-violet rays, etc., the lecture being illustrated by lantern slides and numerous experiments. One of the experiments with selenium, to illustrate the effect of light upon the electrical resistance of this substance, consisted in placing a piece of selenium in circuit with a sensitive relay and a battery. The armature of the relay was connected with a switch operated by a motor, by means of which an electric light circuit could be opened and closed. Light from an acetylene lamp was allowed to fall on the selenium, and when the experimenter's hand was passed quickly between the lamp and the selenium the relay was operated and the electric light circuit was as quickly opened and closed. The normal resistance of this selenium cell was about 200,000 ohms, which dropped to 75,000 ohms when light fell upon it. A possible useful application of the selenium cell was suggested in connection with constantly lighted buoys, which are supplied with a quantity of gas, regularly fed to the lamp day and night. By the employement of a selenium cell in an electric circuit on the buoy it is proposed to cut off the supply of gas at dawn and turn it on at twilight, automatically, thereby effecting a large saving in the consumption of the gas.

Still another important application of the selenium cell in connection with

a recorder and reproducer of speech electrically was shown by the lecturer. This consists of a device by which the transmitter of a telephone is placed in circuit with an arc lamp. The light from this lamp is caused to pass through an opening in a receptacle containing a rapidly moving ribbon of sensitive paper. The slight variations of light, caused by the electrical pulsations set up by speaking into the transmitter, are reproduced on the film transversely across the ribbon as lines of varying degrees of whiteness or translucency when the film is developed. The previous process is then reversed, the film being placed before a selenium cell, the latter in circuit with a telephone receiver and a small battery. Light from a lamp is let in through the opening in the receptacle, with the result that as the film is passed before the selenium cell the varying degrees of opacity of the lines effect a corresponding variation in the resistance of the selenium, and the speech previously spoken into the transmitter is clearly and loudly reproduced in the telephone receiver.

In this relation it may be noted that a direct-current arc lamp, when connected up in shunt with a telephone transmitter, will reproduce speech, the lamp in this case being termed a "speaking arc," or "arcophone." The alternating-current arc has not thus far been found adaptable to this use. One of the theories offered to explain the cause of these sounds issuing from the arc is that the slight variations of current set up by the transmitter produce relatively large variations of temperature in the arc, the temperature varying as the square of the current. These variations in temperature, in turn, effect rapid variations in the volume of the carbon vapour, of which the arc is mainly composed, thereby setting up sound waves in the air around the arc. It has been suggested by Mr. R. A. L. Snyder that this discovery may be employed to enable a speaker to address large assemblies with comparatively little effort, inasmuch as the speech waves set up by a telephone transmitter could be superposed upon the field of an arc light machine, when all the lamps operated from this machine would reproduce the speech.

In a communication recently made to the Paris *Academie des Sciences*, M. Curie announces a further extraordinary property of the marvellous element radium, which was, it will be remembered, the joint discovery of himself and his distinguished wife. It appears that radium has the property of maintaining itself at a temperature of about 2.7 deg. F. above surrounding objects, and apparently does this for an indefinite period. At any rate, no change is found in its properties after a lapse of months. The amount of heat emitted is such that the body is capable of melting its own weight of ice every hour. Where the energy comes from is a mystery; possibly the heat observed merely arises from the energy of the particles radiated from the radium being turned into heat. The velocity of these particles is known to be enormous, perhaps one-tenth that of light. At this velocity the energy of a single grain weight would, if entirely converted into heat, produce 28,000,000 British thermal units, or, say, as much as that due to the combustion of about one ton of good steam coal. It has been suggested that the energy evolved by the radium is merely picked up by it from the space surrounding the salt, and transformed into the heat observed. This, however, does not seem probable, though, according to London *Engineering*, it has the support of Sir William Crookes, since such a transformation would appear to involve a contradiction of the well-established principle of the degradation of energy. So far as is known, the only stores of energy available for such a purpose are of the low-grade type, which would have to be converted into high-grade energy to give rise to the observed phenomenon; and, so far as is known, every transformation of energy naturally occurring takes place in the opposite direction to this. Were radium avail-

able in quantity, it might prove a substantial addition to our stores of energy, though one of which it would be both difficult and dangerous to make any practical application. Indeed, M. Curie has said that he would be afraid to enter a room containing a pound of the element, as he believes it would be fatal to go near it. A glass tube containing a few grains of radium salts, and carried in the waistcoat pocket for a few hours, gave rise to painful sores, the skin in the vicinity of the tube being destroyed. The radiation has also a powerful effect on the nerve substance, and is thus fatal to living organisms, of which the nerve centres are sufficiently near their integument to be within range of the radiation.

At this time of improved forms of construction of tangential water-wheels it is interesting to recall that the early wheels of this class were built almost entirely of timber. The original "hurdy-gurdy" wheel, as told in a recent article in *Engineering*, was usually built of 4-inch timber, and resembled a circular saw having teeth at 8-inch pitch. The sides of the teeth were closed in by planking, forming them into buckets, and the shaft and its bearings were generally also of timber. If the fall was low, rectangular wooden pipes, often held together by wooden wedges and treenails, were used to convey the water to the nozzle; but with greater heads the supply pipe was constructed of sheet iron. This wheel, crude as it was, is credited with an efficiency of 40 per cent., and it is doubtful whether, under the special conditions of the case, it did not prove more satisfactory, from a commercial standpoint, than a regular turbine would have done, in spite of the higher efficiency of the latter, since the hurdy-gurdy wheels could be built on the spot out of local materials.

From a careful historical study of the development of the tangential water-wheel contributed to the American Institute of Mining Engineers by Mr. W. A. Doble in 1899, it appears that the first step in improving this wheel was taken as long ago as 1866, a cast iron wheel having been built in that year on the lines of the hurdy-gurdy, with the difference that the bottoms of the buckets were not closed in, and the water could thus escape towards the centre of the wheel, a certain reactive effect being thereby obtained. The familiar cup-shaped bucket was brought out somewhere about 1870. A water jet striking a cup larger than itself spreads symmetrically, and escapes over the rim with a backward velocity. If this backward velocity is just equal to the forward velocity of the bucket, the whole energy of the jet will have been expended in the bucket, and the efficiency should be unity. Unfortunately, however, though this energy is expended in the bucket, some of it goes in simply generating eddies, and is, therefore, ultimately dissipated in heat. The loss thus arising was reduced later on by the introduction of the now well-known jet-splitting wedge. This seems to have been independently invented by different engineers, but is most commonly associated with the name of Pelton. There is, however, evidence that the idea had previously been formulated on theoretical grounds by Professor Hesse, of the University of California.

Mr. Pelton's own account of his invention is interesting. It appears that one of the cup-shaped wheels already mentioned got loose on its shaft, and, being displaced relatively to the jet, the latter struck the side instead of the centre of the bucket. It was observed that under these conditions the mill which the wheel was driving ran faster. As, however, the eccentric position of the jet caused an end thrust on the shaft, Mr. Pelton proposed first to have two sets of buckets mounted on either side of the wheel, the side thrust on the one set of buckets being counterpoised by that on the other, the jet playing on the dividing line between the two sets of buckets. The step from this arrange-

ment to the splitting wedge, made by Pelton, was obvious, and with this type of bucket, which soon came into extensive use, there came also the claims for very high efficiency. How far these claims are substantiated is even yet a matter of dispute, the results obtained in different careful experiments varying through very wide limits. The highest figure which seems at all well authenticated is one of 91.85 per cent., which is said to have been attained in the case of a 26-inch cascade wheel tested by Professor Hitchcock in the engineering laboratory of the Ohio State University in 1897. This figure was obtained with a head of 163 feet; the flow of water was 2085 pounds per minute, and the bucket velocity, 46.2 feet per second. The wheel ran at 447 revolutions per minute, and gave 35 horse-power on the brake. A similar wheel of larger size, giving 80 brake horse-power, showed an efficiency of 90.04 per cent.

THE uses of the X-rays are many, and sometimes marvelous, in a certain sense; also, there are times when they greatly embarrass those subjected to them. It is reported that peculations have been discovered in the Japanese mint, and some of the employees were supposed to have swallowed gold coins of small denominations. These coins were detected in the stomachs of the suspected persons upon testing them with the aid of X-rays.

A NUMBER of years ago it was proposed to make use of the humming noise producable by a common electric buzzer to induce sleep in cases of insomnia, but it is not known how far or how successfully the proposition was carried out. More recently M. Leduc, of France, has been conducting experiments on the use of the electric current as an anæsthetic, which experiments were performed upon himself. He employed a maximum of 50 volts. The electrodes, which consisted of cotton pads moistened with a saline solution, were applied over his kidneys and upon his forehead, respectively. The current was increased gradually until it reached the maximum in five minutes. Sensation, he found, was suspended gradually, the faculty of speech being first suspended, and afterwards of the remainder of the motor system. This suspension of sensation began with numbness of the limbs. The only unpleasant feeling he experienced during the application of the current and accompanying the suspension of the faculties was the sensation of nightmare. When the current is broken, consciousness is instantly restored, and there is a sense of invigoration. The breathing is more or less obstructed, but the heart is not at all affected. Notwithstanding the apparent harmlessness of this use of the electric current, a feeling of apprehension is raised by M. Leduc's rather ominous remark, in describing his experiments, to the effect that danger to life is prevented by switching off the current immediately the breathing shows indications of ceasing.

DEALING with the subject of spontaneous combustion in a recent paper on insurance inspection and fire hazards before the New England Foundrymen's Association, Mr. J. H. L. Coon mentioned a number of facts which it may be well to remember. Thus, damp lampblack will ignite from the sun's rays. The same can be said of cotton waste moist with lard or other animal oil. Lampblack and a little oil or water will, under certain conditions, ignite spontaneously. Nitric acid and charcoal create spontaneous combustion. New printers' ink on paper when in contact with a hot steam pipe will ignite quickly. Boiled linseed oil and turpentine in equal parts on cotton or linen rags or cotton waste will ignite in a few hours under a mild heat, and will in time create enough heat to ignite spontaneously. Bituminous coal should not be stored where it will come in contact with wooden partitions or columns or against warm boiler settings or steam pipes. This coal should not be very deep if it is to be kept on storage for a

long period. If piled in the basement of a building, it should be shallow and free from moisture, and under good ventilation. That liable to absorb moisture should be burned first. If on fire, a small quantity of water showered on this kind of coal cokes it upon the top and retards any great supply of water reaching the fire, thus necessitating the overhauling of the pile. Iron chips, filings or turnings should not be stored in a shop in wooden boxes. The oily waste which is not infrequently thrown among them adds to the danger of fire from this source. The sweepings from the machine shop, if kept on hand, should never be placed over iron shavings. This mass of disintegrated iron is enough to incite heat and combustion. Iron and steel filings and turnings when mixed with oil will ignite spontaneously after becoming damp. A steam pipe against wood will cause the latter to ignite spontaneously after being carbonised, particularly if superheated steam enters the pipe, thus increasing the heat temperature.

To this Mr. Coon adds that as persistent watchfulness is the greatest safeguard against the breaking out of fires, it is important in a manufacturing or other large establishment to have a system of periodical inspections carried out by the manager, and a regular inspection by a competent man, one who is likely to persevere in its supervision. With most men immunity from fire occasions a feeling of security, and consequently after a few months of careful attention to duty men fall into neglect and perfunctory habits. A daily inspection is not too frequent, and will pay for itself ultimately. Every part of the premises should be looked after. Particular attention should be given to the line of every steam pipe. It should be ascertained that no part of it is in contact with wood, and that no cotton waste or other inflammable substance is near it. The surroundings of every steam boiler, stove or other heating apparatus should be examined, all inflammable material removed from the vicinity, and defects in smoke flues or flue connections or supports should be noted and reported. The open spaces beneath benches, tables and wide shelves and in enclosed belt boxes should be examined for inflammable materials, and these should be removed, and the attention of any person responsible for leaving such material in dangerous position be called to the matter. All places where oils, varnish, lacquers, japans or naphtha, etc., are used or stored should be particularly examined and every precaution taken against fire. Special care should be taken against leakage of these inflammable materials, and to see if any cotton waste or rags or other substances liable to combustible ignition when fouled with oil have been left lying outside of their proper receptacle. The condition of the yard should have attention, and no accumulation of inflammable materials should be allowed against buildings. A careful examination of fire equipments should be made. Every part of the apparatus should be examined, and anything whatever missing should be promptly reported. These notes are general in their application.

ENGINEERING schools and their imperfections were discussed by Professor Dugald C. Jackson in an address delivered at the recent quarto-centennial celebration of the University of Colorado, in the course of which he said that the teaching force of an engineering school should ideally be made up of engineers,—men who have seen some years of successful practice (and preferably continue to hold some practice), who are held in esteem for such by their brethren in practice, but who have a joy in the quiet life of the scholar which is traditionally associated with the colleges, and who may thus be contented when outside of the immediate tide of engineering production. Yet the teaching of engineering is a question of pedagogy rather than of the engineering profession, and it must be dealt with with this clearly in view. Here is one source of

many profound imperfections in existing schools. It is sometimes thought that men who cannot make a success in business life are just right for teaching. This is entirely wrong, and the idea should not be admitted for a moment in any modern technological school. The discontented man who has made a failure in business life will certainly make a failure in teaching engineering. Engineering colleges should avoid "men who are fools in working," even though they are "philosophers in speaking." Enthusiastic men are wanted; they may be young men, if need be; but they must be paid well enough so that they may take places as self-respecting members of the engineering profession, and they must be properly chosen with respect to their qualifications. These men must be good professional engineers; they must possess power and satisfaction gained from engineering research, and from attainments in other lines than those of purely professional acquirement; but sound teaching is their work of first importance. It is very difficult to teach well, but that is no excuse for admitting poor teaching into the engineering schools.

Since the substitution of electric traction for steam locomotives on the elevated railway system of the city of New York so much trouble has been experienced at each recurrence of sleet storms, by which the third rail has been rendered practically useless as a conductor, that even the daily press has demanded the protection of the third rail against the elements, so that the exasperating blockades be obviated. The railway company has thus far depended on scrapers and oil to clear the rail of sleet or to prevent its formation, but these devices have not proven successful. That it is feasible to protect the third rail from sleet appears to be fully demonstrated by the experience of other roads which use the third rail. For instance, the Wilkesbarre & Hazleton Railroad, in Pennsylvania, twenty-six miles in length, running mostly through a mountainous country, protects the third rail by means of a pine plank held directly over that rail by suitable supports. Contact with the rail is made by a shoe which projects at right angles from the car and passes under the pine plank. This device afforded ample protection from the severe sleet storms of the past winter, and it is, furthermore, an additional safeguard against accidental contact with the third rail,—a decided advantage in itself.

The old way in which electric cables were hauled into subway conduits, and indeed the one which still most generally prevails, was to employ a capstan operated by man-power, a tedious, slow process, and it is obvious that any means of facilitating this work in overcrowded city streets is very desirable. In one place a hoisting machine driven by an electric motor is now used for this purpose with much success, the electric motor, on account of the readiness with which it can be controlled, being found well adapted to this service. The current for the motor is drawn from any neighbouring overhead power or trolley wire. In New York city, where trolley wires are not available, a large electric auto-truck, carrying a storage battery and hauling machinery driven by an electric motor, is used for this service. The truck is also capable of carrying one or two large reels of cable. This vehicle is self-propelled to the edge of the manhole of the conduits, when a wire rope is passed over a drum and through a duct to the end of the cable at a distant manhole. When everything is in readiness, the electric motor is set in motion, thus hauling the cable into the duct with a celerity at least three times that of the manually operated capstan method.

JAMES MAPES DODGE

President of the American Society of Mechanical Engineers

A BIOGRAPHICAL SKETCH

By S. Howard-Smith.

MECHANICAL instinct and creative facility were manifested at an early period in the life of Mr. James Mapes Dodge. The leisure of his school-boy days was largely employed in applying mechanical movements and principles to " things of use and things of play," and his work even at this early day was characterised by originality of thought and directness of method.

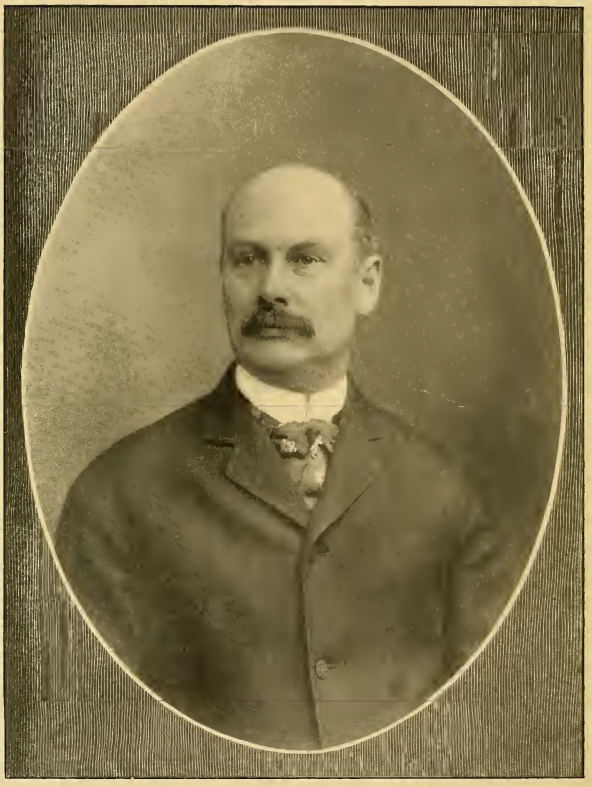
Three years at Cornell University and a fourth devoted to the study of chemistry at Rutgers College, were followed by an apprenticeship at the Morgan Iron Works, in New York City, and several years of practical work in the shipyards of John Roach, at Chester, Pennsylvania. During this period several iron steamships were built at these yards for the Pacific Mail Steamship Company. Among them was the *City of San Francisco*, whose engines and machinery were built under his supervision. Though but twenty-three years of age at that time, Mr. Dodge was also in charge and responsible for the installation of the machinery in the ship and its operation on the successful trial trip which followed.

In 1879 he removed to Chicago, and, as superintendent, took charge of the factory of the Ewart Manufacturing Company, forming a connection with the infant link-belt industry which has never been broken, and in which at present he represents a large interest as president of the Link-Belt Engineering and Dodge Coal Storage Companies.

As an inventor Mr. Dodge is singularly resourceful and direct, reaching his results by the short cut rather than the travelled road, and it has been noted that his original models and designs have rarely been improved by alteration. Of the more than one hundred patents which he has taken out, an unusual percentage has proved commercially valuable, representing prompt and original solutions of present problems and clear foresight of his chosen field.

In executive work Mr. Dodge has had long and eminently successful experience. Sound in judgment and convincing in statement, yet considerate of dissenting opinions, he has ever regarded leadership as the privilege of leading and co-operation as more valuable than obedience. Quick sympathy, a magnetic personality and most genial temper are qualities by which his friends best know him. To grant a request rather than refuse it, to remove obstacles rather than create them, to suggest alternatives instead of condemning an unwise proposition, are all characteristic of Mr. Dodge's distinctly affirmative mind.

The American Society of Mechanical Engineers is to be congratulated on securing Mr. Dodge as its presiding officer. Experienced in executive work, active in the affairs of the society, distinguished as an inventor, broadly conversant with progress in mechanical lines, of wide professional and social acquaintance, successful in his own business, and in the prime of life, he cannot fail in his term of office to justify the choice of the Society for its highest official honour. Mr. Dodge was born in 1852 and is the son of the distinguished authoress, Mary Mapes Dodge.



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E. H. Gary

CHAIRMAN OF THE BOARD OF DIRECTORS OF THE ALLIS-CHALMERS COMPANY, CHICAGO

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CASSIER'S MAGAZINE

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PATENT OFFICE JUN 1 1903

GREAT BRITAIN'S NAVAL SUPREMACY

CONCLUSIONS FROM THE RECENT BRITISH NAVAL DEBATES

By The Right Hon. Sir Charles W. Dilke, Bart., M. P.

What Sir Charles W. Dilke has to say in the following pages will be read with special interest in conjunction with a previous article by Archibald S. Hurd on the same subject in the issue of this magazine for March, 1903.—THE EDITOR.

ON THE CAPTAIN'S BRIDGE

THE debates on the British Navy estimates this year differed from all others within memory of man, and turned almost exclusively on the need for economy, advocated by a small minority, and on the need for a great navy, supported by a large majority in the House of Commons.

Before the main question was reached there was a special debate on the Admiralty scheme for amalgamating the entry and training of the officers of all branches of the service. The division showed an overwhelming preponderance of opinion in the House in favour of the Admiralty scheme; but it is possible that the House felt that it did not understand the question, and was simply not prepared to interfere. The debate left, indeed, on the minds of those who, like myself, did not feel competent to discuss the question, the uneasy feeling that the Admiralty case was less strong than we had thought.

The change is one which evidently, by confining the entry of the engineer officers of the fleet to those nominated as combatant officers are nominated now, takes the engineering department out of the hands of the middle class and gives it to the public-school class,—not in all cases a complete change, but at the least a shift in an anti-democratic direction.

Mr. Haldane, who made what was considered the weightiest speech on the Admiralty side, and who is said to have been consulted in the preparation of the scheme, ingeniously argued that it was essential to take the boys at an early age, and that open competition at such an age was impossible. Those who know the Eton collegers, conspicuous both in the scholarly and in the athletic

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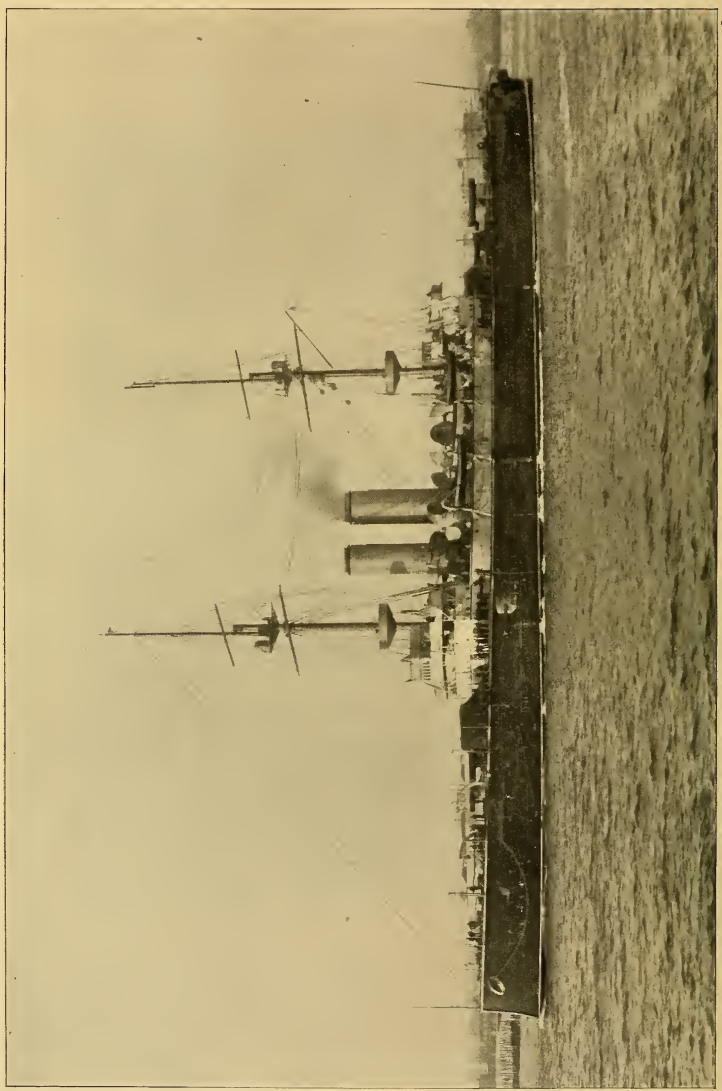

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world, and who remember that the Eton foundation is recruited by fierce open competition at the same early age, wonder at the sweeping nature of Mr. Haldane's statement. Mr. Haldane also said that the change which the Admiralty proposed had been made in the United States with results universally admitted to be excellent.

Surely it is the case, on the one hand, that the change made in the United States is not the same change which the Admiralty is making here; and, on the other hand, that it is not by any means universally conceded that the new American system is, in itself, successful. There is this remarkable fact to be stated upon the other side,—that the French have most carefully considered the very change that has been carried here and have decided that it would be fatal to the efficiency of their fleet. In the report of the Commission of the Budget, charged to examine the Budget of the Marine for 1903, it is recorded that, having the same difficulties to face that we have, the French Admiralty thought of the same obvious way of meeting them. "The plan of a uniform entry for naval officers and engineer officers," it is there stated, "was officially considered. It was hoped to secure by community of origin unshakable similarity of view in these two categories of the personnel. Nevertheless, many examples went to show that uniformity of entry and enlistment do not suffice to consolidate forever that harmony which is indispensable to the sound working of the personnel. The control of the fleet and the commissaryship of the fleet have the same entry, and the controllers are almost entirely obtained from commissaries of the first class of from six to ten years' service, so that controllers and commissaries have, on the average, for fifteen years a common career. It would be rash to affirm that these two bodies have a great love for each other. We should risk, were we to modify the present mode of entry of engineering officers, a doubtful experiment, which, in all probability, would not attain our end. Moreover, and this is the most important point, we should take from our engineering officers their governing great quality,—their practical faculty,

SIR CHARLES W. DILKE, BART., M. P.

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REAR-ADMIRAL LORD CHARLES BERESFORD, C. B., M. P.

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THE CRUISER "GOOD HOPE" UNDER THE WORLD'S BIGGEST SHEAR LEGS IN PORTSMOUTH DOCKYARD

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their profound knowledge of the smallest details of machinery, their technical aptitude for effective direction, acquired by their slow, but necessary, preparation for their rank of engineer officer.

"Our engineer officers have proved their worth. The perfect maintenance of the machinery and of the boilers of our ships in reserve allows us to count without fail upon rapid mobilisation. We have seen in our last campaign in China, and in all our sudden fitting out of ships, our men-of-war ready in a few days to take the sea, without hitches, without any failure to attain all that was expected of the machinery. It is at the moment when the value of our engineer officers is the least doubted that it was proposed to upset completely the entry and the organisation of the body of engineers. Such so-called reform would inevitably be disastrous to our fleet."

Such is the French view, and, trained by Colbert and by Bonaparte, the French understand the principles of

scientific administration. Two matters which were not discussed, and which were the subject only of allusion in the debates, were the great combined manœuvres of the Mediterranean, Channel, and Cruiser squadrons, the history of which is told by a Parliamentary paper circulated during the middle of the debates of March, and the report of Sir Edward Grey's committee, nominally on reserves, but, in fact, on the manning of the fleet, which was circulated on almost the same day. The extraordinary attempt, revealed by the former of these two papers, to establish an old-fashioned in-shore blockade by a fleet possessing overwhelming superiority of strength, without taking account of submarines, failed, as it would fail in war, though in a different way. The navy appears to be divided between those who think that the admiral in command was incompetent and those who think that the Admiralty suggested an impossible plan of operations.

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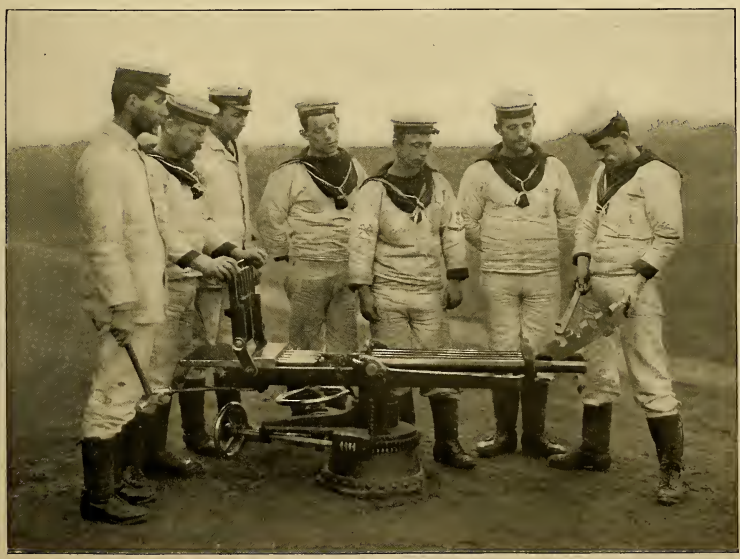

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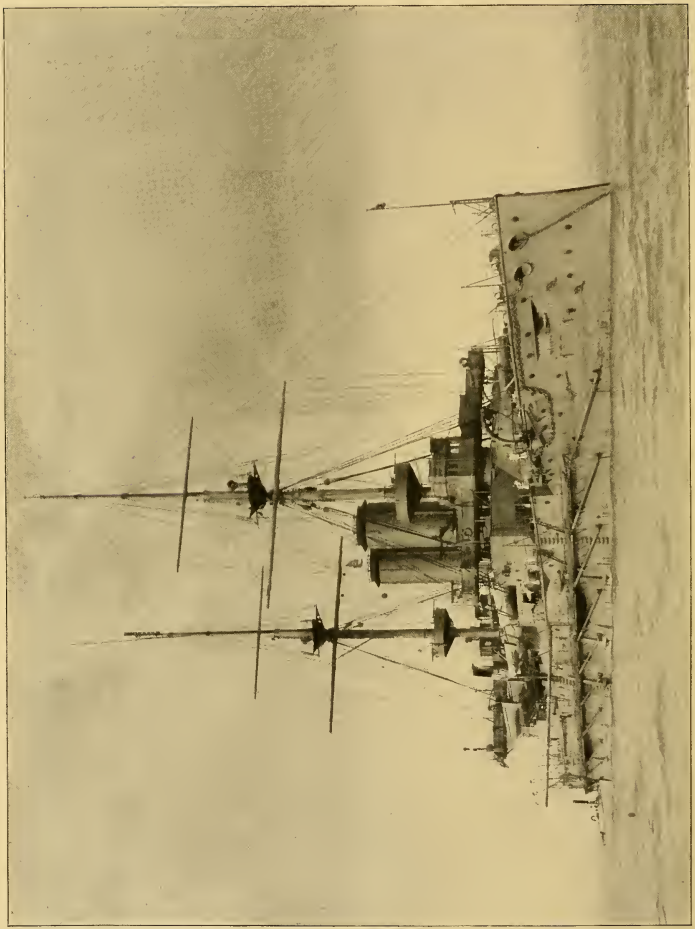

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The light thrown upon the higher training of the navy is suggestive, and the notes of naval progress, published by the Intelligence Department of the Admiralty of the United States, are confirmed in their good-natured strictures. The Americans told us last year that our manœuvres of 1901 showed that the highest branches of the service have "been much neglected during the last few years in England." It is probable that they will tell us the same thing with regard to the Mediterranean manœuvres of 1902. The moral which the Americans drew last year they will probably draw again,—"That those who are designed to act as commanders-in-chief in case of war should, in time of peace, be kept in constant mental communication with their future subordinates."

The other paper which was published about the middle of March, under the too limited title, "Report of the Naval Reserves Committee," is of even more permanent interest. It was briefly named in Parliament on the third reading of the Naval Reserves Bill on

ADMIRAL SIR COMPTON DOMVILLE, K. C. B., COMMANDER-IN-CHIEF OF THE MEDITERRANEAN SQUADRON, ALWAYS THE MOST IMPORTANT FIGHTING FLEET OF GREAT BRITAIN

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HUGH CAKELEY ARNOLD FOSTER, M. P., PARLIAMENTARY SECRETARY TO THE ADMIRALTY.

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April 1. The evidence taken before the committee has not been printed, and, it may confidently be said, will never see the light. As I was one of those who were examined by Sir Edward Grey's committee, I am, on the other hand, familiar with the nature of the great questions which in reality occupied their minds and which involved not only reserves, but the whole future of the fleet, and am bound to accept what is evidently, from their report, their view, namely, that to discuss these questions in public would be to give assistance to our rivals or our enemies.

The important matter upon which there exists a difference of opinion between the public and the Admiralty concerns the question of the wastage of the personnel in war. It is clear from speeches which have been made by Lord Goschen and others that, while the public thinks we should need in a naval war an enormous number of additional men, the Admiralty are of opinion that the wastage of ships would be more

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rapid than the wastage of trained men. It is evident that successive First Lords of the Admiralty have been advised that their ships will be laid up in great numbers for repairs, but not lost with all hands, and that the seamen who will be available after the first naval engagements will suffice for the ships that will still be present in the line.

The subjects of less importance but of greater novelty which are illustrated by the report of Sir Edward Grey's committee, and which are not too dangerous to discuss, are those of naval volunteers and of colonial sailors. As regards the latter, it is certain to those who know the colonies that we must draw a line between cases where, as in Newfoundland, local conditions allow us to expect the success of colonial training, and cases such as those of Australia and New Zealand where the rate of wage is so high as to make the acquisition of a large body of well-trained men improbable, except at a cost which is prohibitive.

With regard to naval volunteers, the committee have expressed a confident opinion in their favour, and the result has been immediate legislation. I am one of those who view the proposal with the greatest doubt, but not with misgiving. It does no harm. In exceptional cases it may do good. There is no ground whatever for opposition, but it would be unwise to place much depend-

ence upon the volunteer element for the manning of the fleet in war.

There are instances of the need for local naval defence which stand wholly apart from the general question of the command of the sea. It is possible that even as regards invasion of Great Britain some security would be given, more perhaps against panic, which is certain, than against invasion itself, which is improbable, by local naval defence within the territorial waters, and especially in the shallow waters which ironclads cannot reach. Just as the strongest advocates of the blue-water school, and those who the most confidently believe in the doctrine of the command of the sea, admit the patrol of the Solent and of the mouth of the Thames by guard boats at night, so there may be ground, even in the minds of the most rigidly orthodox upon the question, for patrol of the shallow waters generally by torpedo-boats, perhaps by small, fast rams, which, in time of war, might be manned by volunteers from the boating population.

The case of Jersey is, I am convinced, a clear, though it is, perhaps, an isolated, case in favour of volunteers. Jersey lies so close to a great number of French *défense mobile* stations, which in the Bay of St. Michel are, in fact, mobile offensive stations, that raids are certain. No general command of the sea can prevent them. The French, coming from a number of their river stations, all of them almost within sight of Jersey, are continually making excursions round that island in time of peace, and in these days of submarines no blockade could be close enough to prevent these excursions in time of war.

Jersey has a large French population, and it would be the object of the enterprising commanders of the French torpedo squadrons to keep the compatriots

MARINES AT THE MAXIM ON THE CRUISER "TERRIBLE"

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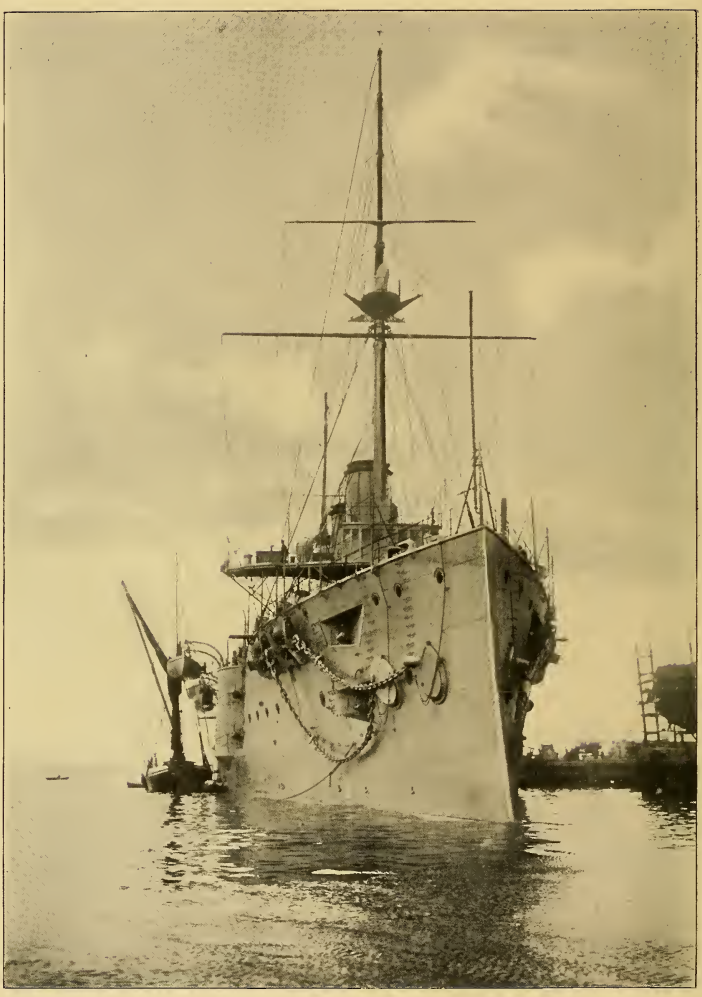

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supplied with arms and Jersey in a state of simmer. Here is the ground for the creation of a local destroyer squadron, manned by Jersey fishermen, acquainted with the local rocks and tides. Some of them would, no doubt, be reserve men trained in Jersey; but some of them might, with advantage, be volunteers. Such defence would be cheaper and more effective than War Office defence by infantry and artillery and big guns. The service of volunteers on board the

COALING AT SEA

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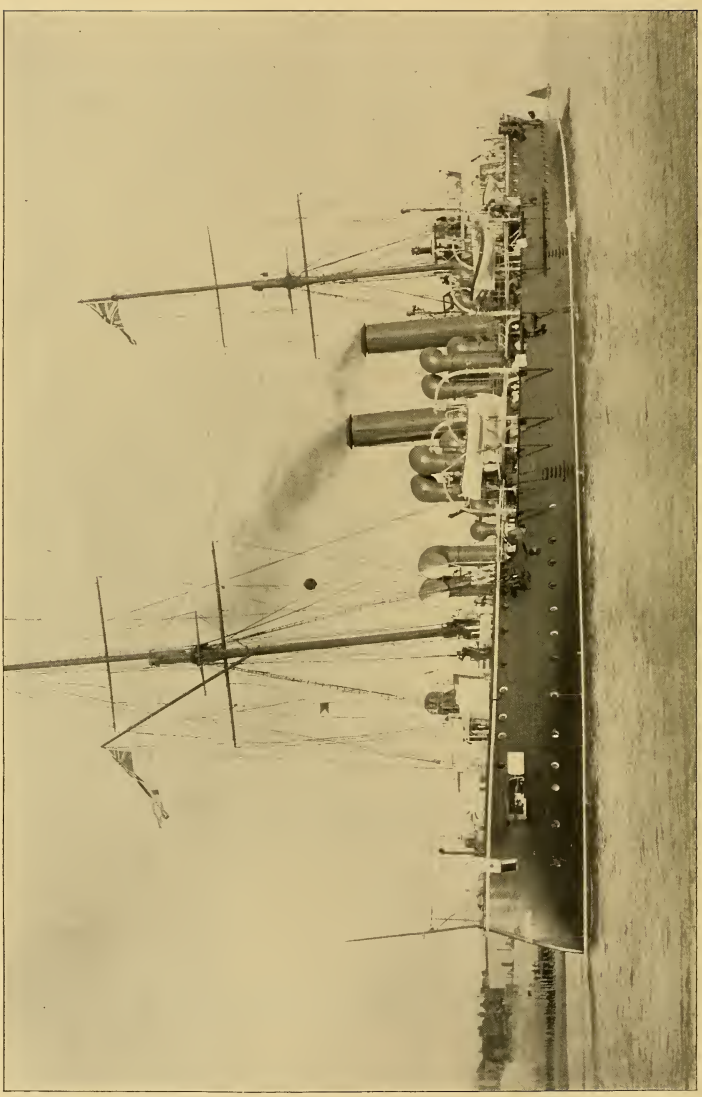
battleships and first-class cruisers of the principal fleets is, in my belief, a dream.

The main recommendation of Sir Edward Grey's committee formed Clause 4 of the bill which passed through the House of Commons in April, unopposed. It is the introduction of short service at the discretion of the Admiralty. When we remember that a Parliamentary session was consumed over the introduction of short service to the army by Lord Cardwell, and that naval objection to short service has hitherto been more unanimous than military objection to short service in the army, it is an amazing fact that no opposition whatever should have been offered to so revolutionary a change. There is no restriction in the clause, but we elicited from the representative of the Admiralty the expression of opinion that one-fourth of the personnel would be the outside number of short-service men, and it is rumoured that the terms of five years for active service and seven years in the reserve are the periods of service for the minority which the Admiralty have in view. The British fleet will still contain a larger proportion of long-service men than does the French, which alone among the fleets of Continental powers has a considerable long-service element,



THE NEW CRUISER "PANDORA," FOR THE MEDITERRANEAN SQUADRON

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GOING DOWN IN ONE OF THE BRITISH SUBMARINES

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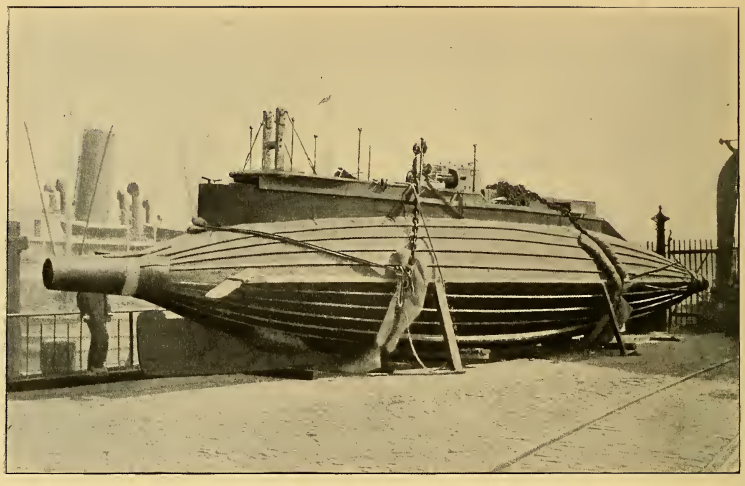

ONE OF THE GERMAN SUBMARINE TORPEDO BOATS

and is increasing it until it may soon become half the personnel of the French fleet. The overwhelming need for the change, which is intended to reduce the extraordinary disproportion between our active service ratings and our reserve, was not denied by any organ in the press or by any voice in the House of Commons.

ADMIRAL SIR JOHN FISHER, K. C. B., LAST YEAR RELINQUISHED COMMAND OF THE MEDITERRANEAN SQUADRON AND IS NOW LORD COMMISSIONER OF THE ADMIRALTY

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The main debate in the Commons turned, as has been said, on economy, which was generally disavowed in favour of economy on the army estimates, and the rates of the army are contrasted with the picture of the present position of our fleets. The Mediterranean squadron has been strengthened, and is relatively in a better position than that which it occupied when the Navy League made its great attack, or at that earlier period of Fashoda when its strength was already sufficient to cause the French Admiralty to give to the French Government that information which led them to pack Tunis full of troops.

The Mediterranean fleet is strong enough to view with equanimity the extreme strategic difficulty of the position which, in face of Russian activity in the Black Sea, it now occupies. The Channel squadron will soon be strong and homogeneous. The home squadron is the weak point, and some time will still

pass before it comes up to our needs. The position, however, looking to the present state of Europe, is sufficient and satisfactory. What we have to do is steadily to keep up the advantage which we hold, and by the wise selection of our admirals for high command, and by the training of those captains who will be our admirals of the future, to ensure the possession by us, in the event of war, at least of equality with our rivals in the high commands.

The naval debate in the House of Lords which took place on March 24 turned on the two-power as against a three-power standard. It was an incident in the general defence debate started by Lord Rosebery, and the speech of the First Lord of the Admiralty constituted what we call a new departure. In all previous debates upon our naval standard it had been assumed, by every speaker except myself, that our standard was one of equality with, or superiority to, two powers, and the phrases had been used as though they were equivalent. There had been no suggestion from either front bench of what we call "a sufficient superiority." On the other hand, I had always said that Lord Spencer's programme had given us a position which, while not above a two-power battleship standard, was sufficient, with the advantage of a single command, to cause three powers to hesitate to attack us.

Putting things more plainly, I had assumed that an attack on us by France and Russia, in which we should have to consider no other power, was most improbable; but that a state of things might easily arise in some years' time when we should have to expect dangerous pressure by Germany, France, and Russia unless our naval position continued to be such as to make these three powers, under all the circumstances, feel that they were not clearly stronger than us at sea.

In the recent debate Lord Selborne explained the two-power standard in my sense. He told the peers that there had never been any question of mere equality with two powers except in respect of battleships; that, as regarded cruisers, we had always, for the protection of our trade routes, had an infinitely higher standard. Moreover, the present Board of Admiralty, while not abandoning a two-power standard in battleships, were not content with mere equality, but thought that the two-power standard meant a reasonable probability of victory.

An able article in the "Shipping World," by an examination of our ex-

REAR ADMIRAL ATKINSON-WILLES, SECOND IN COMMAND OF THE HOME SQUADRON

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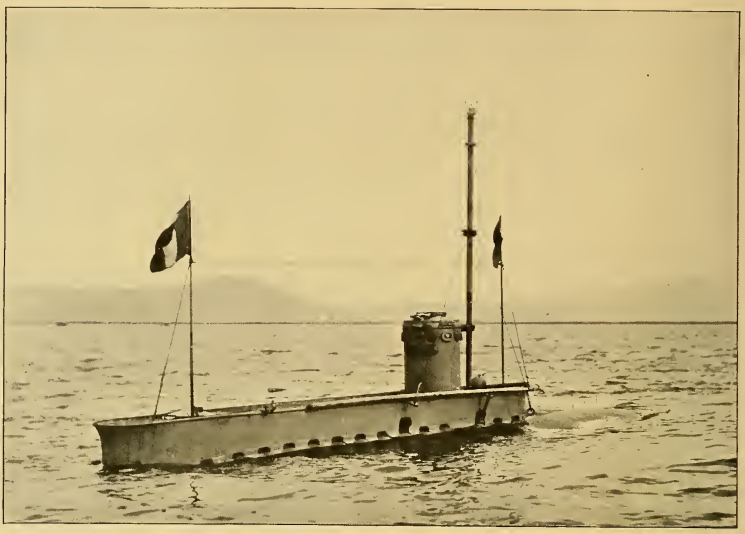
penditure makes out that we are exceeding a three-power standard, and are steadily forging ahead of France, Russia, and Germany combined. A mere examination of these figures, however, is clearly inconsistent with the Admiralty view that the necessity of the protection of our trade routes, and consequent expenditure on cruisers and personnel, make our standard applicable to battleships alone. We build more cheaply than do foreign powers. On the other hand, our battleships have to be bigger, and our personnel is more costly, both because we have to rely on volunteer



THE FRENCH SUBMARINE "GYMNOTE"

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REAR-ADMIRAL W. H. FAWKES, COMMANDER OF THE CRUISER SQUADRON

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enlistment and because our ships are better manned in time of peace. The fact that we have hitherto had only long-service men, and, even after the principles of Sir Edward Grey's committee are applied, shall have a larger proportion of long-service men than France or Germany, also increases our expenditure, as compared with that of foreign powers.

Our battleships have to be larger than those of other powers, for the reason that we have to be prepared to fight in the Mediterranean at a greater distance from an effective base. It is easy to conceive circumstances under which there might be much difficulty in coaling our ships, and it has never been our policy to build coast-defence or second-class battleships. A battleship differing from our own in size only on account of inferior coal capacity, and consequently lessened radius of action, may in some cases be as useful to Germany and France, who possess small ships, as our larger and more costly vessels are to us.

It is difficult, however, to consider standard without any reference to the rapidly increasing strength of France in submarine and submersible craft. Those of us who agreed with the Admiralty in doubting for some years the value of the submarine fighting ship are now, unfortunately, proved wrong as regards France, though we are still right about ourselves. It is impossible to fail to see that, while our submarines are of the limited value which was to be expected, the French have made astounding progress in submarine navigation.

My own knowledge of the men who are building the French submarines makes me fully credit their assertions as to the progress which they have accomplished, which was unexpected by them when the three earliest submarines were built, eleven or twelve years ago. I am inclined to think, indeed, that as regards guns, as well as in the matter of submarine navigation, the French have an advantage over us.

The statement which we used to make that the submarine is a defensive weapon, and, therefore, inapplicable to our naval power, which must be offensive, while suitable to the French, has ceased to be true. The French submarines and submersibles have become offensive weapons; and we can no longer count upon the French remaining on the defensive in the Channel, while we have always known that in the Mediterranean they would come out and fight in the event of war. The range of the submarine is not yet sufficient to affect the naval engagements of the future in the Mediterranean; but if the same progress be maintained in French invention which has been shown in the last three years in the development of the submarine, the cutting of the French communications with Africa and the holding of the Mediterranean will be a matter of increased difficulty.

As regards the Channel, if the admirers of the submarine are right, the invasion problem will, in a few years' time, assume a renewed importance. I am one of those who in recent years have feared panic rather than invasion. But looking ahead, it is impossible to deny that the problem has been complicated by the improvement of the French submarine, and that we cannot afford to rest until our constructors and our officers and men come more on a level with the French Navy in this respect than they are at the present time. It is not, of course, that invaders will be brought across in submarines, but that submarines may be used to clear the narrow seas of those who otherwise would be able to destroy the invaders' ships.

The enormous increase in the number of the French submarines, accompanied by a decrease in the remainder of their programme and in the manning of their battleships, means that more and more the French are turning their attention to the submarine as the weapon of the future, and that an increasing proportion of their officers and men are being trained for service beneath the waters instead of upon the surface.

THE ELECTRIC FURNACE

By J. Wright

THERE are few inventions in the electrical field which have benefited the chemist and metallurgist more than that comprised under the general title of "electric furnace." Up to, comparatively speaking, a few years ago, the highest attainable temperature by any known artificial means was 1800 degrees Centigrade, or, possibly, with exceptional facilities and the exercise of great care, as high a temperature as 2000 degrees Centigrade may, in some cases, have been attained, though the exact limit is questionable; certainly it does not rise much above the latter figure. Thanks, however, to the indefatigable researches of Moissan, Siemens, Borchers, Cowles, and some other investigators, we now possess a means for the artificial production of temperatures far above this limit, which enable us to fuse and otherwise treat commercially such hitherto refractory substances as chromium, platinum, carbon, and even the once indestructible crystalline form of that element, the diamond.

Generally speaking, electric furnaces may be divided under two main headings, namely, those in which the heating effect is produced by the electric arc established between two carbon or other electrodes connected with the source of current, commonly known as arc furnaces; and those in which the heating effect is produced by the passage of the current through a resistance, which either forms part and parcel of the furnace proper, or is constituted, by a suitable conducting train, of the material to be treated in the furnace. The principle of this latter type is analogous to that involved in the heating to incandescence of the ordinary electric lamp filament, and such furnaces are, as a class, known as resistance furnaces.

The earlier electric furnaces naturally assumed an experimental form, and, of these, that devised by Moissan, the celebrated chemist and investigator, is probably the simplest. It is an arc furnace, and consists of two chalk blocks, bored out at their centres to receive a carbon crucible which encloses the centre or hearth of the furnace proper. Into this cavity pass two massive carbon electrodes, through openings provided for them in the walls of the structure, which is held together by massive clamps. Suitable terminal connections to the carbon rods are provided, exterior to the furnace, and the arc established between their inner extremities when the current is turned on plays over the centre of the crucible, heating its contents.

A furnace of this type, though its capacity is limited to a single charge of the crucible at each operation, has, nevertheless, proved itself of extreme utility in laboratory practice, and is a very efficient source of heat in that the hearth or centre of activity is entirely surrounded by refractory, non-conducting walls. Very little heat is consequently lost by diffusion or radiation.

A somewhat more elaborate modification of Moissan's original furnace has been devised by Messrs. Ducretet & Lejeune, of Paris, and is shown in Fig. 1. It consists of a refractory chamber *R*, built of fire-brick or some other suitable material, and provided with an opening *A* through which the substances to be treated may be introduced. *C C* are carbon rods, supported in massive tubular clamps *T T*, which are water-jacketed to keep down their temperature

to a safe limit. *B* is a carbon or magnesia crucible, forming the hearth of the furnace, and containing a charge of the material to be treated, whilst *W* is a removable window, or inspection opening, fitted with ruby glass, through which operations requiring only a moderate heat can be watched whilst in progress. When utilised for higher temperatures, this glass slide is replaced by a slab of refractory material, such as fire-brick. The carbons *C C* project through the walls of the furnace, at right angles to each other, and the necessary separation of their inner extremities for the establishment of the arc takes place at a point just above the mouth of the crucible *B*, as shown. A system of tubes leads into the interior of the chamber *R*, and serves, when required, for the introduction of special gases, with which it may be necessary to cause the contents of the crucible to enter into chemical combination. A horseshoe permanent magnet *M*, manipulated at the exterior, exerts a repellant force upon the arc, directing it down into the crucible as desired, after the manner of a blow-pipe.

Sir William Siemens was the first to apply the electric arc furnace to commercial operations, and his apparatus and experiments were described in a paper read by him before the Society of Telegraph Engineers. According to this astute investigator, who seems to have, in a measure, grasped the conditions and general principles necessary to the successful operation of an arc furnace,—no mean conception, when one considers the general lack of knowledge on the subject which prevailed at the time (over twenty years ago),—the advantages in favour of the electric furnace as a source of heat are that, theoretically, the heat obtainable is unlimited; fusion is effected in a perfectly neutral atmosphere; the operation can be carried on in a laboratory, without much preparation, and under the eye of the operator; and that the limit of heat practically obtainable with the use of ordinary refractory materials is very high, because in the electric furnace the fusing material is at a higher temperature than the crucible; whereas, in ordinary fusion, the temperature of the crucible exceeds that of the material fused within it.

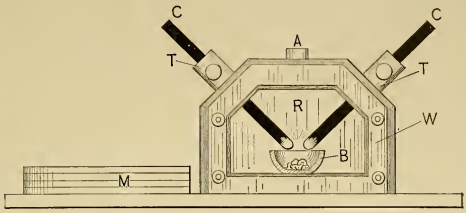


FIG. 1

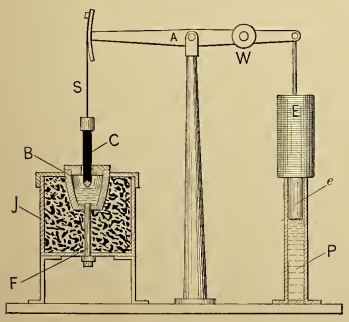


FIG. 2

The general principle of the early Siemens arc furnace is represented in Fig. 2, in which *B* is a refractory crucible of plumbago, magnesia, lime, or other suitable material, which may be varied according to the nature of the substance to be dealt with. It is supported at the centre of a cylinder or jacket *J*, and is packed around with broken charcoal, or a similarly poor conductor of heat. Being thus isolated, as it were, from the surrounding atmosphere, it retains its heat, and very little is lost by diffusion. The negative electrode consists of a massive carbon rod *C* passing vertically through the centre of the lid of the crucible, and free to

move vertically therein, though the clearance opening is, for obvious reasons, very small. The rod *C* is suspended from the lower end of a copper strap *S* which conducts the current from it, being attached at its upper end to the curved extremity of a horizontal beam *A*. The other side of the beam is provided with an adjustable weight *W*, and carries, suspended from its extremity by a hinged joint, a hollow soft iron cylinder *e*, forming the core of the solenoid *E*. *P* is a dash-pot arrangement in which the cylinder works, the tendency of *E* being to raise it out of *P* against the counteracting force of the weight *W*, thus lowering the negative

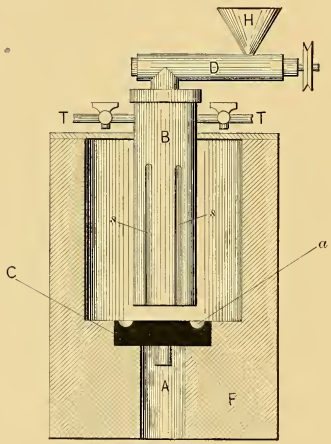


FIG. 3

electrode into the crucible. The solenoid winding is connected as a shunt across the two electrodes. The positive electrode *F*, which may be of iron, platinum or carbon, consists of a rod of one or the other of these materials passing up through the centre of the base of the crucible. The furnace was originally designed by Siemens for the fusion of refractory metals and their ores; consequently, once the action is started, electrical contact is established between the lower electrode *F* and the semi-metallic mass in the crucible, and the arc continues to play between the surface of the mass and the movable carbon rod *C*. As the current through the furnace increases, that through the shunt winding of the solenoid diminishes, and the weight *W* coming into play, causes its end of the beam to descend, thereby raising the negative electrode *C* and restoring equilibrium.

The Willson furnace is essentially a modification of Siemens' original form, the solenoid regulation of the upper movable carbon being replaced by a worm and hand wheel, whilst the furnace is made continuous in operation by the provision of a tapping hole for drawing off the molten products. This type of furnace was employed in the manufacture of calcium carbide, which, when drawn off in a molten state, is much purer than the ingot or broken lump form, in which the greater bulk of that commodity is placed on the market.

The Parks carbide furnace, devised by W. P. Parks, of Chicago, is of the arc variety, and provides for the production of calcium carbide in the molten state. It is represented in Fig. 3, and consists of a vertical cylindrical structure *F* of refractory material, provided with a carbon hearth *C*, which, at the same time, acts as the negative electrode. It has an annular channel *a* cut in its upper surface, which latter is flush with the inner floor of *F*. This channel collects the molten carbide formed, and it drains down, to be ultimately drawn off at *A*. The upper, positive electrode *B* consists of a massive, hollow carbon cylinder, in the lower half of which, or the portion inside the furnace *F*, are cut radial slots *s s* which subdivide the electrode and tend to set up a circle of arcs around the space bounded by the hearth. *T T* are gas supply pipes, ending in hydrocarbon burners inside of *B*, which primarily heat the raw material as it passes down the hollow centre of the electrode. The feeding is effected from a hopper *H* by an Archimedian screw working in the casing *D*.

An arc furnace, utilised in the production of aluminium from alumina, either *per se* or alloyed with other metals, is that utilised in what is known

as the Herault process, carried on by the Swiss Metallurgical Company, at Neuhausen. It consists of an outer iron casing or container *F* (Fig. 4) resting on an insulating base. This container is lined with massive carbon plates,

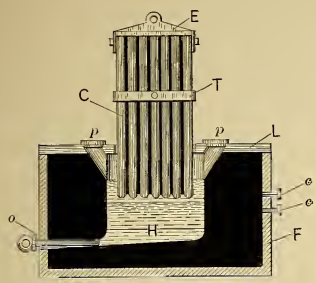


FIG. 4

cemented together with tar or suitable conducting material, and so arranged as to form at the centre a recess or hearth *H*, an outlet *o*, from the bottom leading out to the exterior of the furnace, and providing for drawing off the molten metal.

A series of copper pins *c c* driven into the iron walls of the container serve as a means of terminal connection to the carbon blocks, which constitute one electrode of the furnace, whilst the other, *C*, consists of a number of carbon plates, placed face to face, like the leaves of a book, the spaces between being filled in with some good electrical conductor, such as sheet copper. The composite electrode, thus built up, is mounted in a frame *E*, by means of which it can be raised or lowered as required, and terminal connection is secured by means of an encircling clamp *T*. The electrode *C* passes through a clearance opening in the lid *L* of the furnace, which consists of graphite plates; openings *p p* are also provided for the introduction of the raw material (alumina), thereby making the furnace continuous in operation.

The furnace is charged with alumina, as already indicated, and the electrode *C* having been lowered, the arc is struck. The heat thus set up fuses out the metallic aluminium, leaving the oxygen free to combine with the carbon of the electrode *C*, which it does, forming carbonic oxide gas. The molten metal collects at the bottom of the hearth and is drawn off through the outlet *o*, fresh alumina being fed in, and the height of the electrode *C* being regulated as the operation proceeds.

The King furnace is also of the arc variety, and is utilised in the manufacture of carbide in ingot form. It consists of a fire-brick chamber, through the roof of which passes vertically the upper, adjustable electrode. The lower, fixed electrode is carried by a small truck, or trolley, which runs along rails at the base of the structure, and acts the part of crucible or hearth. The lime and carbon are fed into it down lateral channels in the walls of the furnace, and are caused to combine by the heat of the arc set up. The upper electrode is gradually raised as the raw material is fed in, until, at a certain point, the truck becomes filled with a block or mass of calcium carbide, and is then

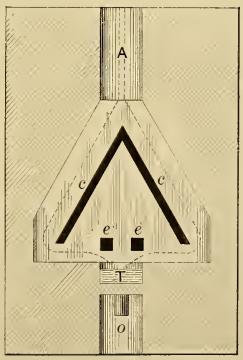


FIG 5

wheeled out of the furnace to discharge its load. Whilst fusion is in progress a slight reciprocating motion is given to the truck, which serves to shake the charge well down and introduce fresh portions of it into the path of the arc

proper. The Chavarria-Contardo arc furnace for the manufacture of calcium carbide possesses several novel points. Its general principle is represented diagrammatically in Fig. 5, where *e e* are the electrodes, running parallel to one another and slightly above the axis of the channel or trough *T*, which forms the hearth; *c c* are thin graphite plates, built up to form a roof-shaped structure, which becomes itself intensely hot when the furnace is active. The raw material is fed in at *A*, and, passing over the upper surfaces of *c c*, receives a preliminary heating of no mean degree; it then passes down, taking the course indicated by the dotted lines, under the electrodes *e e*, and into the trough *T*, where it is

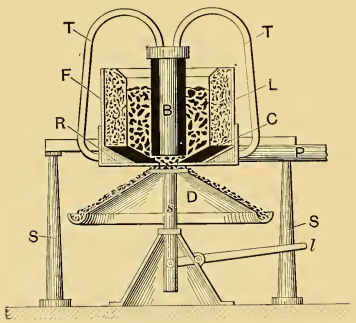


FIG. 6

subjected to the most intense reflected heat of the arc. The molten carbide formed is drawn off by way of the outlet *o*.

The disposal of the gases, especially carbon monoxide, resulting from the reactions in a carbide furnace has long been a stumbling-block to the manufacturer in that any attempt at modifying the furnace to this end resulted in undesirable complications and increased prime cost. This has been, in a measure, overcome in the Frölich arc furnace for carbide manufacture, invented by Dr. Oscar Frölich, of Streglitz, Germany. The general arrangement is shown in Fig. 6, and consists of a cylindrical iron crucible *F*, mounted on standards *S*, and tapering at its base to a central discharge orifice.

A lining of fire-clay *L* protects the cylindrical wall, whilst the inner surface of the conical base is covered by the carbon electrode *C*. The remaining electrode consists of the massive carbon cylinder *B*, which is hollow, and depends, with its lower edge just over the discharge orifice, the arc taking place between the two edges of the carbons. Tubes *T T* lead from the upper portion of the carbon cylinder *B* to the annular chamber *R*, just outside and enclosing the space bounded by the lower electrode *C*. The gases of combustion pass up the centre of *B*, which acts as a flue, and down by way of the tubes *T T* to *R*, where they mingle with air, admitted through perforations in the casing, and are consumed, the final products passing out through the discharge pipe *P*.

The raw material is fed into the mouth of the furnace around the central electrode, and, passing through the annular arcing region at the bottom, where it becomes converted into carbide, falls onto the adjustable conical table *D*. This is provided with a lip around its lower edge, and is mounted on a stem *s*, which, gearing with the lever *l*, permits of its being raised or lowered, according as the operation of the furnace is intermittent or continuous.

The Denbergh furnace for the manufacture of sulphuric and phosphoric acids, and also "water-glass," or sodium ortho-silicate, is shown in Fig. 7. It consists of an ordinary fire-brick structure *F*, lined at *r* with a refractory material impervious to the gases produced in the reactions, an outlet for which gases is provided at *o*. The body of the furnace is contracted below, as shown, and the outlet *R* for the fused products is led up within the walls themselves, from the point of lowest level to another point of higher level, which defines the depth of converted material contained within the furnace.

The lid *L* carries a charge inlet *i* and a hopper *H*, the feeding being secured mechanically by a reciprocating movement communicated to the piston *p*, which works in a cylinder *c*, carrying a

definite quantity before it at each stroke. The electrodes *E E* are of carbon, passing through terminal sockets in which they are capable of motion in a direction corresponding with their axes, which permits of feeding as they wear away,

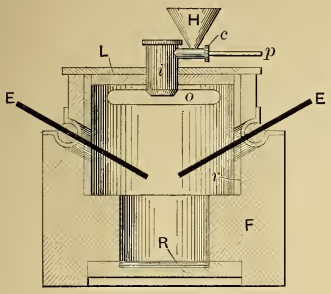


FIG 7

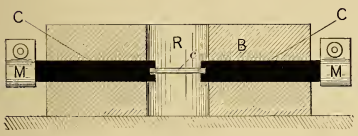


FIG. 8

whilst the sockets, in turn, are mounted in a species of swivel joint, which allows the angle of inclination, and consequently the height of the arc, to be varied at will.

Koller's arc furnace is of a simple description. It consists of a longitudinal chamber, with massive carbon blocks projecting through the end walls. A series of carbon blocks, supported in line with the terminal electrodes, are arranged along the chamber at regular intervals, their number varying according to the voltage. The arc is thus split up into series, and a number of heated regions are secured in the centre of the mass of raw material which is packed around the blocks.

The Henriveux furnace, for the manufacture of glass, consists of three steps or slabs of refractory material, forming a species of cascade, the mixture to be fused being fed from a hopper onto the top step, whence it descends by gravity over the remainder. The heat from a powerful arc is directed upon each of the three steps, and the mass, in passing through the series of three, emerges finally in a molten state, and is collected in a suitable receptacle at the bottom where it is maintained in a state of fusion by a gas or coke fire. It is said to be a very wasteful process in that a considerable quantity of the heat developed in the arcs is lost or dissipated without performing useful work.

Passing now to resistance furnaces, Borchers' is typical of that class in which a core, forming part of the furnace itself, is heated by the passage of the current through it, and imparts its heat to the surrounding mass of material contained in the furnace. It is represented in Fig. 8, and consists of a block *B* of refractory material, through the centre of which passes an opening *R* forming the crucible, or centre of activity, into which is fed the material to be treated. This space *R* is bridged by a thin carbon rod *c*, which is attached, at its extremities, to two massive carbon electrodes *C C*, passing through the walls of the furnace and fed with current through the large metal clamps *M*. These massive electrodes serve to conduct the current, without undue heating, to the smaller rod *c*, through which it passes, in turn, raising it to a very high temperature, owing to the resistance offered to its passage by a conductor of considerably smaller cross-section, and forming, as it were, a central, heated axis to the material contained in the crucible. It thus

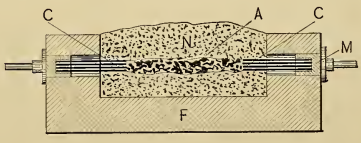


FIG. 9

diffuses its heat throughout the mass, from its centre outwards.

The Gibbs resistance furnace is based on the Borchers principle, a carbon rod, or rods, of small section being supported between massive carbon blocks set in cast-iron sockets let into the brickwork.

The novelty of this invention, however, lies in the position of the small resistance rods. These are located above the furnace charge and do not come into actual contact with it at all, the heat being communicated by reflection from the domed roof.

The Acheson furnace for the manufacture of carborundum is a somewhat rudimentary device, in that it is built up and pulled down again for each charge of raw material dealt with. It is represented in diagram by Fig. 9, in which *F* is a rough fire-brick structure, through the end walls of which project the electrodes *C C*, consisting of composite bundles of carbon rods set in massive metal clamps *M*. The space between the two electrodes is bridged by a conducting path of coke *A*, which constitutes the distinct core of the furnace, and relegates it to the class of which Borchers' furnace is a typical example. This core is packed round with the raw material *N*, consisting of coke, sand, sawdust and common salt. The process of conversion is said to be far from economical.

A resistance furnace, based upon the fundamental principle of the Nernst lamp, has been devised by Drs. Nernst and Glaser. The resistance, or heater, is cylindrical, electrical connection with it at the top and bottom being secured by an annular packing of some conducting oxide, held in place by iron clamps and bolts. The hollow cylinder is surrounded by a jacket of oxide, loosely packed between it and an outer cylindrical sheath,—an arrangement which prevents undue waste of heat. The heating cylinder, which consists of a mixture of magnesia, calcium carbonate, alumina, and silica, is closed by a lid, and the substance to be treated is either packed directly into it or contained in a crucible located within it. In the former case the cylinder is protected internally by an additional lining of pure magnesia, coated with graphite to give it an initial conductivity.

The Cowles furnace, again, is typical of that class of resistance furnace in which the path of high resistance consists of the material to be treated and does not form part of the furnace proper. The Cowles furnace first made its appearance in 1884, and takes several forms, all more or less similar in general principle, but differing in such details as affect the class of work for which they are intended.

In its simplest form it consists of an oblong fire-brick structure, provided with a lid, in which are one or more vent holes to permit the escape of the gases generated. Massive carbon electrodes are introduced horizontally through the two ends of the furnace, electrical connection with them being secured, in an early form, by a species of tubular gland through which each electrode passed, and which was filled with copper shot. In passing to and fro through these glands the carbon rods set up a kind of rolling friction with the shot, and fairly good electrical contact was thus established between them.

A preliminary lining of granular charcoal was given to the furnace, which, being a bad conductor of heat, prevented undue loss due from radiation and diffusion. Inside this lining, again, was packed the partially conducting mass to be heated, forming a chain between the two carbon electrodes. When the current was turned on this mass became heated by the passage of the current through it, after the manner of the carbon filament in the ordinary incandescent lamp.

In a later form (Fig. 10) of the Cowles furnace charging funnels *F F* were introduced through apertures in the lid, whilst the hearth sloped from either end to the centre, at the lowest point of which was provided an outlet *o* for drawing off the molten products. *C C* are the carbon electrodes; *G*, the glands containing the shot; and *c*, the lining of non-conducting charcoal. The funnels *F*, by a judicious feeding process, provided a means of keeping the resistance of the column of material fairly uniform at all points, thus ensuring an even distribution of heat throughout the mass.

The Cowles furnace for the treatment of zinc ores was also of the resistance type, and is represented by Fig. 11,

where R is a long cylinder of fire-clay, mounted in a brickwork setting, and surrounded by a jacket of some refractory material J which is also a bad conductor of heat. The inner end of the cylinder R is effectually closed by a flanged disc of carbon C, which also

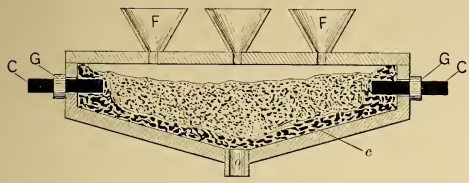


FIG. 10

constitutes one electrode of the furnace, the other taking the form of a plumbago crucible P, the convex base of which fits into the outer extremity of the cylinder R and forms a removable seal. Further, by way of an aperture a in the wall of the crucible, the metallic zinc passes over into it by distillation, and is collected therein, a chimney or outlet c serving to carry off the gases and fumes produced. The charge of broken zinc ore is, as before, spread evenly along the cylinder, so as to form a semi-conducting chain between the two electrodes.

The Cowles furnace for the manufacture of aluminium alloys partook of the nature of Borchers' furnace, although it had not, strictly speaking, a continuous resistance core of its own. Two massive tubular electrodes, provided with a means for manual adjustment, carried close-fitting cores of smaller section, which inclined to one another and actually met, forming a conducting core of high resistance at a point in the centre of the furnace, immediately under the aperture of the feeding hopper. These smaller electrodes, together with the raw material fed on to them at the point of meeting, formed a conducting link of high resistance between the main electrodes, and the heating effect of the current was thus localised and confined to the point at which it was most needed, namely, at the feeding centre of the cavity.

A circular form of resistance furnace, devised by M. R. Conley, and intended mainly for the reduction of iron ores or the manufacture of steel, consists of a cylindrical fire-brick structure, the inner wall of which is contracted to form a narrow opening at about two-thirds of its depth to the hearth proper, which lies below. At the contraction is introduced a circular set of electrodes of segmental form, made of the usual compressed carbon mixture, and isolated from one another by intervening segments or pillars of fire-brick.

The electrode segments constitute an even number, and are connected alternately to the positive and negative poles of the source of current. Means of adjustment are provided which allow the segments to be fed radially as they wear away. A similar circle of segmental electrodes surrounds the central portion of the furnace proper, or crucible, which is located below the contraction and provided with an outlet for drawing off the molten metal as it forms. By a suitable manipulation of the current and connections to the furnace, it is possible with this device to secure a combination of heated zones or paths through the

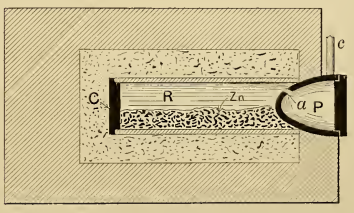


FIG. 11

mass of material under treatment, the position of which can be varied at will, so as to penetrate to all parts and secure a homogeneous and uniform fusion.

The Readman-Parker furnace for the manufacture of phosphorus was invented independently by these two gentlemen

in 1888, and they subsequently combined their ideas to form a community of interests. It consists of the usual fire-brick structure *F*, Fig. 12, and feeding hopper *H*, the furnace being hermetically sealed, in order to exclude atmospheric air. A discharge flue *A* carries off the gases and vapours formed during the process, and the interior of the chamber is contracted at its lower portion, as shown, to form a hearth. Multiple electrodes *E E* are employed, facing one another in two rows, passing through the side walls of the structure, whilst smaller electrodes *e e*, below them, which can be brought into closer proximity, are employed to start the current flow. These are subsequently withdrawn, and the action, which resembles that of a resistance furnace with a conducting path formed of the material under treatment, is maintained between the main electrodes *E E*.

The ingot carbide furnace recently patented by Mr. Parker should have a decided future before it. The principle of its construction is represented in sectional plan in Fig. 13, in which *R* is a cylindrical retort or crucible, lined throughout with carbon *C*, forming one electrode, the other being a massive carbon block of rectangular section *B*, which is supported at the centre of the retort, and is of such dimensions that its corners approach very closely to the inner carbon walls of that vessel. The raw material is fed in at hoppers on either side of *B*, their position being indicated by the circles *a* and *b*. Whilst working, the crucible and its contents revolve, thus constantly bringing fresh portions of the mass within the zone of activity, whilst by a carefully proportioned train of gearing the electrode *B* is gradually raised at such a rate that its lower extremity is always immersed at a constant depth in the mass under treatment, whilst an ingot of finished carbide is gradually built up beneath it in the crucible.

A series of patents have been recently granted in the United States on electric furnaces for the manufacture of such comminuted products as pigments, abrasives, oxides, refined metals, and a miscellaneous collection of similar character. The general arrangement consists of an arc, or resistance, furnace, with which is combined an air blast device, playing

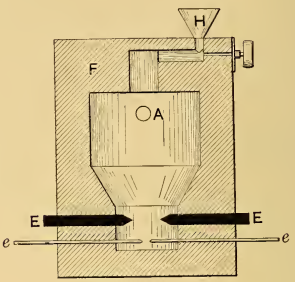


FIG. 12

either immediately onto the furnace contents or upon the vapours rising from it. An example will serve to demonstrate the general principle involved.

Fig. 14 represents a furnace of this description, devised by C. S. Lomax, and patented as recently as March, 1902. It is intended for the manufacture of the various commercial oxides of lead and tin. A refractory block *F* has a narrow channel *c* cut in its upper surface; this constitutes the hearth of the furnace, and is of uniform cross-section for about the centre third of its length. At each

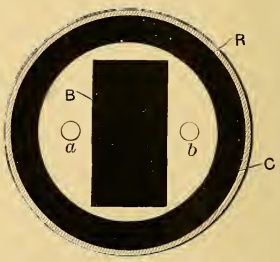


FIG. 13

extremity it merges into a deeper and wider wedge-shaped cavity, in either of which is placed, vertically, an electrode; *T* is a main, supplying cold or heated

air to the discharge jets *t t*, which are set at such an angle that the air emerging from them is projected downwards into the central trough or channel; *L* is a cover or screen, which collects the products and guides them into the chamber *R*.

The mode of procedure is exceedingly simple. The channel *c*, together with its enlarged ends, is filled with the molten lead or tin to be converted; the current is turned on, and that portion of the molten column, bounded by the narrow central channel, immediately attains a considerable temperature, owing to its smaller cross-section. When the required heat has been reached the air blast is brought into play, causing the finely divided metallic particles to combine with its oxygen, the resulting compound being carried over into the chamber *R*. This form of furnace is adaptable to making a variety of oxides, the necessary changes in chemical combination being brought about by varying the respective temperatures of the air blast and the molten metal.

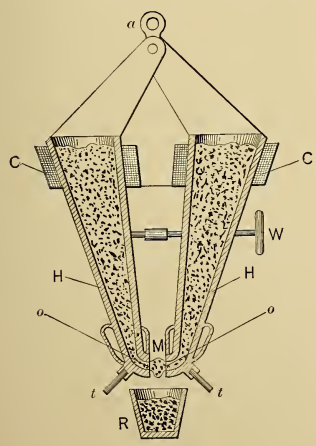


FIG. 15

Ruthenburg's electro-magnetic furnace is another practical example of the proverb "Necessity is the mother of invention." One of the purest sources for the extraction of metallic iron is "iron-sand" and similar ores, the process of treating which has hitherto been hampered by their finely divided state and consequent clogging of the smelting furnaces. Ruthenburg's invention has

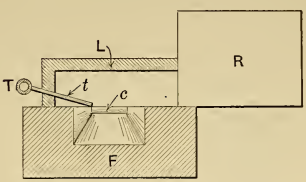


FIG. 14

in view the preliminary agglomeration of this sand, with the object of thus converting it into a form more suitable for the ordinary operation of smelting.

His furnace is represented in Fig. 15, and consists of two similar cast-iron hoppers *H H* hinged together at the point of support *a*, and into which the iron-sand is fed at equal rates. The discharge orifices *o o* are opposite to each other, and the distance between them can be varied at will by the hand-wheel and worm *W*. The two hoppers constitute the electrodes, terminal connection with them being secured as shown at *t t*, where the discharge nozzles are also water jacketed; *C C* are magnetising coils, encircling the hoppers, and having their windings connected either in series with, or in shunt across, the hoppers. Their office is to magnetise the individual particles of the sand, causing them to adhere together temporarily and thus assist in forming a self supporting mass *M* across the discharge apertures. This mass is subjected to the maximum heating effect, and the semi-molten product drops away into the crucible *R* placed to receive it.

A novel type of resistance furnace, patented independently, with some slight variation of detail, by Colby, Ferranti, and Kjellin, is worked on the inductive principle, and consists of an annular, or helical, channel in a refractory base, filled with a conducting, or semi-conducting, medium, which con-

stitutes the furnace charge, and has a heavy current induced in it by a surrounding coil of many turns, carrying an alternating current. The device, in point of fact, acts as the closed-circuit secondary of a step-down transformer, and is said to be admirably adapted for the fusing of such metals as platinum,

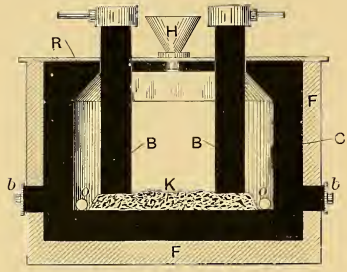


FIG. 16

which, if exposed to the atmosphere during the process, as in the ordinary type of furnace, occlude oxygen and other gases in their mass, which lead subsequently to blow-holes and other imperfections in the casting.

The experience of late years in the construction and use of electric furnaces trends towards the establishment of the resistance furnace as a type more readily capable of efficient regulation. This is further accentuated by the fact that overheating is, to a considerable extent, possible, and indeed prevalent, in many types of furnace, especially those of the arc variety. Scientists and others, unversed in the possibilities of the electric furnace as a source of artificial heat, hailed its introduction with delight as a means of overcoming many of the difficulties previously imposed by the limitations of temperature. In so doing, they in many cases overlooked the very simple fact that it is possible to have too much of a good thing, and the consequent tendency was to overrate rather than underrate the temperature required for various commercial processes.

Experience, however, has exposed this fallacy, and, as a natural result, we turn to that type of furnace which offers the best means of regulation and the absence of excessive variation, viz., the resistance furnace. Here again we are beset with further difficulties, for, if we employ a portion of the charge itself as a high-resistance column, excessive variations creep in, owing to the changeable nature of the column with the reactions taking place within it, whereas, if we employ a definite core of small cross-section, as in the Borchers class, the capacity of the furnace is limited, and the cost of its upkeep is increased by the very necessary and frequent renewal of the conducting-rods.

With a view to minimising these various drawbacks, Mr. H. I. Irvine, of Niagara Falls, has brought out a resistance furnace in which the heated column consists of a fused electrolyte, maintained in a state of fusion by the passage of the current, and communicating its heat by radiation and diffusion, to the encircling charge, which is packed around it.

The general construction of this furnace, which was mainly designed for the manufacture of phosphorus, is represented in Fig. 16. It consists of a refractory structure *F* lined with carbon *C* and fitted with a domed roof *R*, in the centre of which is a hopper *H*. Two vertical carbon electrodes *B B* descend vertically through *R* to within a short distance of the hearth, whilst a possible variation in the direction of the heating effect is provided by lateral electrodes *b b* connected with the hearth itself. The action of the furnace is first started through a mass of coke *K*, which forms a bridge between the electrodes *B B*, and is subsequently maintained by the fused slag from the furnace charge, which flows down between the electrodes and is maintained at constant level by the overflow outlets *o o*.

As pointed out by Mr. Carl Hering, the fire-brick or other refractory lining of all furnaces, when heated, becomes a conductor, after the manner of a Nernst lamp glower. Though unavoidable, this is a contingency which, with furnaces of the resistance type, at least, must be taken into account, in that it

increases the total conductivity of the device and necessitates a corresponding increase in the working current. He further points out that the heat thus communicated is not lost, except in a small degree, consequent upon the decrease in the thickness of the non-conducting walls and the diminution of their heat conserving qualities.

Equally important with the selection of an easily regulated and comparatively invariable electric furnace ranks the question of temperature determination. At the enormous temperatures developed in the electric furnace all previously known methods of temperature measurement, whether by thermometer or pyrometer, desert us, in that the constituent parts of these various apparatuses will not stand the direct application of such terrific heat. Here, again, stern necessity has been the means of inspiring investigators to action, with a view to discovering some efficient method for the measurement or comparison of these high temperatures.

Fery's suggested method for determining the high temperatures usually encountered in electric furnaces consists in a practical application of Stefan's law, which is to the effect that the radiation of an absolutely black body is proportional to the fourth power of its absolute temperature. Kirchoff has proved that the interior of an enclosure of which the walls are at a uniform temperature is equivalent to an "absolutely black body," *i. e.*, a body which absorbs all the heat imparted to it, giving it out again by radiation, and not by reflection. In this connection, therefore, the interior wall of an electric or other enclosed furnace may be regarded as an absolutely black body, a small aperture in which does not materially affect the conditions governing this definition.

Fery's practical application of this law to the measurement of furnace temperatures consists in a species of telescope, with a fluospar objective; this telescope is placed in line with the aperture in the furnace wall, and, receiving the heat radiated therefrom, concentrates it upon a small thermo-couple. By an inner diaphragm, regulating the number of rays which reach the thermo-couple, the device is rendered independent of its distance from the furnace wall. The fluorspar objective, by its absorption of radiant heat, reduces the sensitiveness of the arrangement by about 10 per cent.; but, notwithstanding this, it has proved of extreme utility, owing to its enormous range, and its applicability in such cases as those with which we are dealing at the present moment, where other generally accepted methods are out of the question. The actual temperature is, of course, obtained from a specially prepared table or curve, and is read from the electro-motive force recorded by the thermo-couple.

Another, somewhat crude, method of measuring furnace temperatures, into which the personal element is liable to enter, causing an error of judgment, consists in a telescope, as before, mounted on a convenient stand, and placed in line with a small aperture in the furnace wall. Inside the tube of the telescope is located a small incandescent lamp, which can be energised by one or two battery cells, and the current through it, and an ammeter placed in series with it, regulated by a suitable switch and rheostat. The principle upon which its action depends is that which involves the apparent disappearance of the filament, when raised to the same degree of incandescence as the furnace lining and viewed against the latter as a background. If the lamp be inactive, the filament appears as a black line; at equal incandescence it becomes invisible, whilst if its state of incandescence be above that of the furnace, it assumes the appearance of a white line. By regulating, therefore, the current through the lamp until the filament apparently disappears, its temperature is made equivalent to that of the furnace, and the result is read on a specially prepared table. The limit of the apparatus is 3600 degrees Fahrenheit, so that for electric furnace work its field of utility is somewhat limited.

In the preceding paragraphs the writer has by no means covered the entire field of development of the electric furnace, but has confined himself to a

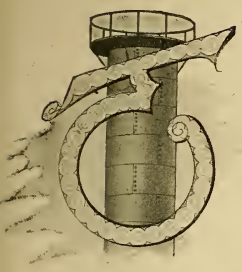
brief description of those examples which serve as a general type of the class to which they, respectively, belong. The subject is a large one, and its comprehensive study would fill a volume of no mean dimensions, whilst its importance, from a chemical and metallurgical point of view, must not be underrated.

At the end of the year 1900 the power used in electric furnaces was estimated at 225,000 H. P., of which 185,000 H. P. were employed in the manufacture of calcium carbide, 27,000 H. P. in the manufacture of aluminium, 11,000 H. P. in that of copper, whilst carborundum was responsible for the output of some 2000 H. P. Any gain, therefore, in the construction or working of electric furnaces, however slight, or apparently worthless, provides food for serious reflection, in that it may be the means of saving large sums of money annually.

PIG-IRON CASTING AND CONVEYING MACHINERY

ITS DEVELOPMENT IN THE UNITED STATES

By E. A. Uehling



THE world's production of pig-iron has increased from less than four and one-half million tons in 1850 to over forty million tons per annum in 1900. At the former period the United States was producing at a rate somewhat greater than one-half million tons, or less than 13 per cent. of the world's output; whereas, fifty years later,—in 1900,—the production of pig-iron in the United States had risen to over thirteen and three quarter million tons, or over 34 per cent, of the world's production. To-day the United States is turning out pig-iron at the rate of eighteen million tons per annum; nearly fifty thousand tons per day; an average car-load per minute.

Prior to 1850 blast furnaces were built of heavy masonry in the form of truncated pyramids, 30 to 40 feet square at the base, and not over 40 feet high (Fig. 1). The favourite location was against a hillside, to save elevating the material by hoist. Water was the principal motive power. Heating the blast was the exception rather than the rule, and the hot-blast stoves in use were primitive affairs, heated with coal or wood oftener than with gas. The average daily output did not exceed ten tons of iron. The iron was run into sand moulds or chills in the form of pigs, at intervals determined by the judgment of the founder, and cleared away at leisure.

In the early fifties anthracite coal had begun to displace charcoal with increasing rapidity in the Eastern iron districts, and block coal was taking the lead as furnace fuel in Western Pennsylvania and Ohio. Steam blowing engines began displacing the water-driven blowing tubs or bellows, and were employed exclusively in the newly erected plants. All the furnaces had open tops, allowing the bulk of the gas to escape. For generating steam and heating the blast

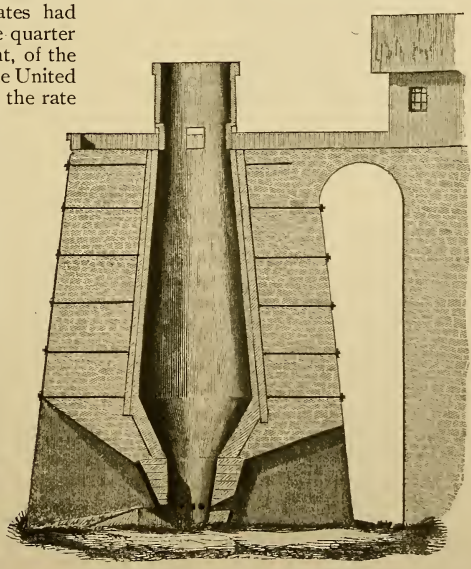


FIG. 1.—A BLAST FURNACE OF 1850. STONE CONSTRUCTION

coal or wood had still mostly to be depended upon, assisted by as much of the gas as could be coaxed down through inadequate flues by insufficient draught stacks. The average temper-

FIG. 2.—A BLAST FURNACE OF 1875. IRON CONSTRUCTION

ature of blast did not exceed 500 degrees, and a pressure of over 2 pounds was the exception.

A favourite construction was to locate the boilers and hot-blast stoves on a level, or a little above the top of the furnace on heavy masonry work. By this construction more of the gas was utilised and better results were obtained. The iron was tapped off twice in twenty-four hours, running out from three to ten tons at a cast. Carrying out the iron and moulding up for the next cast was only a minor part of the work, performed by the keeper and his helper.

Ten years later the rich ore deposits on Lake Superior had been discovered. Coke was becoming the recognised furnace fuel. The direct-acting, vertical-blowing engine had made its advent. Great improvements were made in furnace construction. The stone-mason work was being abandoned, and the Scotch type of furnace (Fig. 2), consisting of cast iron columns and mantle ring, on which rested the fire-brick lining incased in a heavy sheet-iron jacket, was generally adopted.

The height of the furnace was increased to 50 feet and over. The open top still prevailed; but more liberal and better arranged gas flues, assisted by larger and higher draught stacks, made available a greater proportion of the waste gas. Increased boiler plant, new and more powerful blowing engines, together with enlarged and improved hot-blast stoves, furnished a greater volume of air at a better pressure and a higher temperature. The heat of the blast attained 700 to 800 degrees, and was delivered at a pressure of three and one-half to four pounds. An enriched burden (a fair percentage of the high-grade lake ores being mixed with the leaner native ores), smelted at a higher rate, brought the output per furnace up to forty to fifty tons per day.

Furnaces of the larger output were tapped three times in every twenty-four hours, running out ten to twenty tons at a cast. To handle this amount of iron the double casting bed was resorted to. One side was moulded up and got ready for the succeeding cast while the iron was broken and carried out from the other. By this arrangement the time to clear away and mould up the beds was increased to sixteen hours from twelve previously, which gave ample time to complete both operations; and although iron carrying had already commenced to be a formidable task, and required workmen of more than ordinary physique, no difficulty was experienced in getting the iron removed from the cast houses.

In the decade from 1875 to 1885 the most important improvements were introduced into the construction and equipment of blast furnaces, namely, the closed top,—Parry's hopper and bell,—and the general application of Siemens' regenerative system, in the form of the Whitwell and Cowper fire-

brick hot-blast stoves (Figs. 6 and 7).

The fire-brick stoves being more efficient than the iron-pipe stoves, required less gas for heating the blast; consequently, the increased volume of gas due to the closed furnace tops became available for raising steam. The boiler plants were increased, and new and more powerful blowing engines were added. Existing furnaces were raised and enlarged. Ten to 15 feet were added to the height, bringing this up from 50 to 60 and 65 feet. The block coal having been displaced by coke, new furnaces were built 70 to 75 feet high. These improvements quite doubled the outputs of the blast furnace, bringing the average daily production of the improved furnaces close to 100 tons in 1885. In some of the newer plants 150 tons were not unusual, and the 200-ton line had frequently been passed in the larger furnaces using all coke and lake ores.

At the above rate of output the breaking and clearing away of the iron becomes a formidable task. A furnace making 100 tons and over must clear at least four times in twenty-four hours. With double casting beds, this still left twelve hours in which to break and carry out the iron and mould up the beds for the second succeeding cast. With the exception of selecting and handling the men with the necessary strength and constitution, no great difficulty was experienced. Yet when we stop to consider that an iron carrier must be able to pick up and carry six to ten paces, over a bed of loose hot

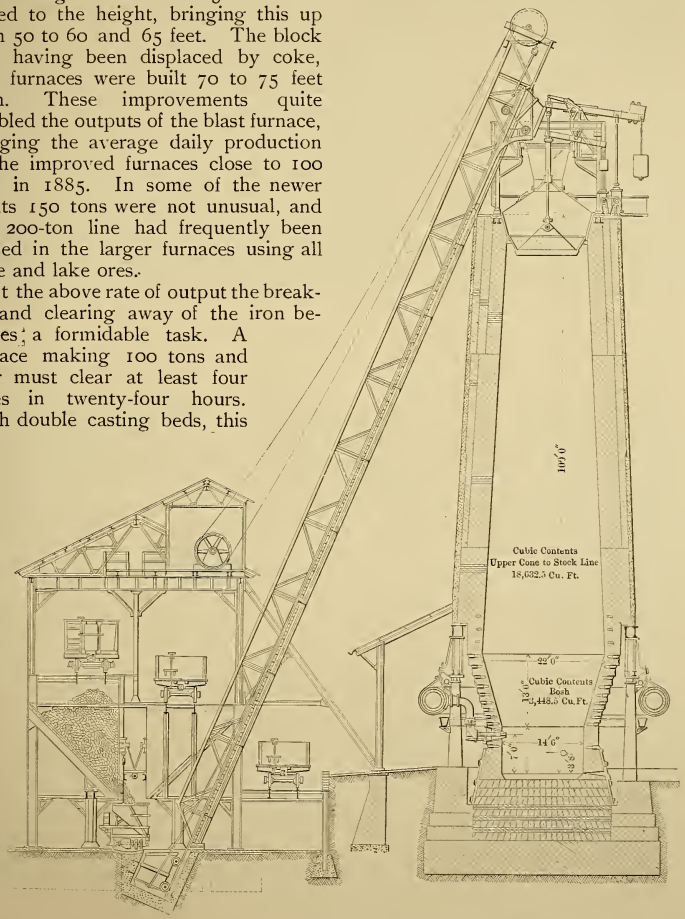


FIG. 3.—VERTICAL SECTION OF A MODERN BLAST FURNACE

FIG. 4.—MAKING A SAND CAST FROM A BLAST FURNACE

FIG. 5.—BREAKING UP THE PIG-IRON

sand, a chunk of rough iron weighing 100 to 125 pounds, throw it into a truck or car, and repeat this operation 250 to 300 times in the limited time in which it must be done, we can readily see that it was not always easy to find men of the requisite strength and endurance. And the march of progress had but fairly begun.

By 1890 outputs of 300 tons per day had become more frequent than those of 200 tons five years previous. The average production of the better equipped furnace had risen to 150 tons and over. The cast beds were increased to the full extent of the available room and were still too small. The number of casts had to be increased from four to six, and more, in twenty-four hours. This necessitated the breaking of the iron hot, and thus added to the already arduous task of carrying the iron the almost unendurable condition of working over red-hot iron with heavy bars and sledge hammers, prying the pigs from the sows, and breaking the latter into lengths that could be handled. This imposed condition required that the iron carrier must, in addition to the strength and endurance necessary simply to carry the iron, have a fireproof constitution, to enable him to endure the heat, as well as the physical exertion.

As the severity of the iron carrier's task increased, the number of men willing to perform it, and able to stand up under it, decreased. Increased inducements in the way of higher wages and greater indulgence had to be offered. Thus available men became more scarce, more difficult to get, and still more difficult to handle. Under these circumstances the clearing away of the pig-iron caused many times more trouble and worry to the furnace manager than all the rest of the plant put together. It was a most frequent occurrence, especially in hot, summer weather, to be called out in the small hours of the night to find both sides of the cast house full of iron, jumpers* by the score, many

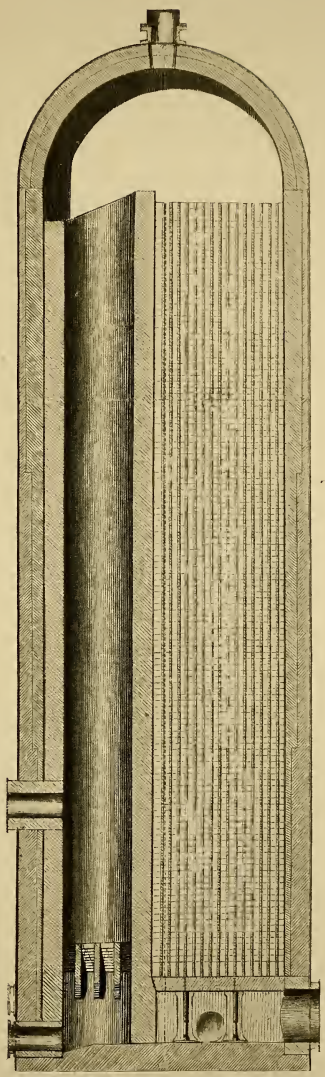


FIG. 6.—A COWPER HOT BLAST STOVE. THIS AND THE WHITWELL TYPE HAVE DISPLACED THE IRON PIPE STOVE SHOWN IN FIG. 8

* Jumper is the name given to double, treble, or quadruple pigs formed when the core or ridge of sand which should separate them is washed away, which will always happen when the flow of iron gets beyond control.

beds probably sheeted† beyond recovery, and not infrequently a large portion of the beds covered with molten slag half a foot deep.

The furnace having been held in beyond its proper casting time, filled with iron above the line of danger; no iron carriers in sight; more than likely they were also full. That the stress of the emergency, the provoking circumstances of having been harshly disturbed in the midst of much-needed sleep and rest to face such a chaos of red-hot iron, slag, and human perversity, would burst open the safety valve to the innermost consciousness of the most sedate furnace manager, and permit an efflux of general epithets and special compliments, rich in quantity and quality, will cause but little surprise. While the profusion of choice language would not clear away the mess, it helped to sober up the iron carriers, impressed workmen with the gravity of the situation, and put the furnace manager in a better mood to direct the work with coolness and energy. Not infrequently the blast had to be taken off at once to avoid the wholesale burning of the tuyeres and the risk of a possible breakout. All the available labouring force about the works would be summoned, often including the carpenters, blacksmiths, and general repair hands. Thus, after several hours' extraordinary exertion, at great expense, and the loss of one-quarter to one-half day's output, order was once more restored and the regular process resumed.

Occurrences like the one just described took place, and do to this day take place, at intervals more or less frequent, and in a degree more or less serious and vexatious, at every blast furnace in existence producing 200 tons and over of iron per day, and not provided with proper mechanical means for handling the pig-iron.

When it is considered that men for carrying the pig-iron are obtained only from the lowest ranks of unskilled labour, and that hardly one man in twenty is capable of performing the task without undue exertion, that the work must be performed in a specified and limited interval of time, under conditions of heat which, in summer time, often become quite intolerable, we can hardly blame them for being independent, much less for occasionally getting drunk.

The task of breaking and carrying out the iron from the casting beds of even a moderate-size furnace is not a fit one for human beings. If it were possible to employ horses, mules, or oxen to perform this work, the Society for the Prevention of Cruelty to Dumb Beasts would have interfered long ago, and rightfully so.

"Necessity is the mother of invention," and when we consider the direness of the former in this case we may well wonder why she remained barren so long.

† When the beds are allowed to run too full, all the pigs become tied together by a sheet of iron covering the cores. In either case, it is very difficult to break up and remove the iron.

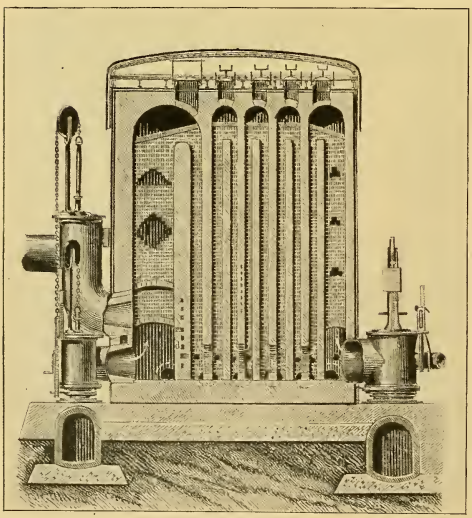


FIG. 7.—VERTICAL SECTION OF A WHITWELL HOT BLAST STOVE

The fact is, that conceptions were numerous; but most of them succumbed in the embryotic state, and many others resulted in miscarriage. Among the comparatively few births recorded, the

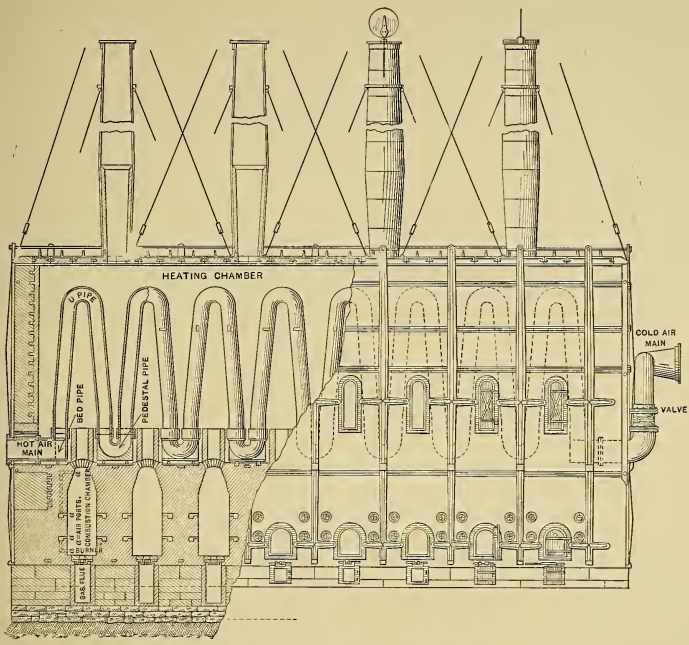


FIG. 8.—AN IRON PIPE HOT BLAST STOVE

freaks predominated, and the babies of real merit and promise gave no end of trouble to their sires and nurses. Great faith, much ingenuity and endless perseverance were required, and a great deal of money had to be expended before the casting machine was so far perfected that it did its work satisfactorily.

The difficulties of casting and handling pig-iron successfully by mechanical means are very great. This will be readily understood when we consider that the iron is received from the furnace in a molten condition, and at a temperature far above its point of fusion; that this intensely hot, liquid iron must be evenly distributed into a very large number of moulds,—about twenty to a ton, or a thousand for an average cast of fifty tons; that since intermittent pouring is practically impossible, the stream of iron must be gauged with great regularity, and must be directed accurately into each individual mould in an interval of time that will just fill them, or the moulds must be carried to the stream of iron in an endless and properly-timed procession, and provision must be made that no iron be lost through the spaces separating the moulds from one another. There were other difficulties too numerous to mention.

James Scott, superintendent of the Lucy furnaces, at Pittsburgh, was the first to make intelligent and systematic

FIG 9.—CARRYING OFF THE PIG-IRON AFTER COOLING

experiments for the purpose of getting away from the cast house difficulties altogether. He has also done more than any other man to overcome the many difficulties that were encountered in the development of the casting machine. Up to the time Mr. Scott undertook his experiments, no one had departed from the old lines. Relief was sought, and, to some extent, gained, by increasing the area of the cast beds, and by providing permanent cast iron moulds, and where all this was obviously insufficient, overhead travelling cranes and pig-breaking machines were provided.

From all this Mr. Scott made a most radical departure. He tapped the iron from the furnace into large ladles of about fifteen tons capacity. These ladles, being mounted on a special car and provided with proper gearing for tilting, were drawn by a locomotive to a convenient place away from the furnace where there was provided a pit, 14 feet deep, and 6 by 8 feet in area. This pit was filled with water and provided with a chain elevator carrying strong iron buckets perforated with numerous holes. The ladle being in position, was now slowly tilted so that a gentle stream of molten iron flowed into the pit. When a comparatively small stream of molten metal is poured into a large body of water the sudden chilling effect produces granulation. The elevator having been put in motion when pouring began, brought up the granules of iron from the bottom of the pit, as fast as formed, and deposited them in a railway car placed under the discharge spout of the elevator. All the water escaped through the perforations in the bucket. In this manner the iron tapped from the furnace was deposited into cars ready for shipment, with but slight physical exertion, and without having to be touched by hand.

These experiments, very beautiful in conception, and, because of simplicity of method and cheapness of operation, most promising as to economical results, did not, however, prove commercially practical. The granulated form of the iron which resulted gave rise to difficulties which could not be overcome:—

1.—The fine granulations, hard as diamonds, proved fatal to the wearing parts of the elevator.

2.—The granulated form proved to

be very objectionable to the consumer, principally because of the difficulty of rehandling the material.

3.—Granulated iron, because of its great surface exposure, oxidises very readily, and cannot be stored without protection against wind and weather.

Undaunted by disappointments, Mr. Scott continued his experiments in a modified form, but holding fast to his conviction that cast bed extensions, overhead cranes, pig breakers, and the like could give only partial relief at best, and that to completely overcome the cast house troubles, the casting into pig beds must be entirely abandoned.

In his efforts to overcome the difficulties due to granulation, he undertook, and experimentally, at least, succeeded in casting pigs direct under water. These experiments led to the adoption of an endless series of travelling moulds, moving at a regular rate of speed, and continuously filled while passing under a properly regulated stream of iron pouring from the ladle.

An investigation of the art along the lines which seemed most promising of success revealed the patent on a "Method and Means for Casting and Conveying Iron and Other Metals," granted to the writer, about the time, or perhaps a little prior to the time, Mr. Scott began his experiments at the Lucy furnaces. In this invention Mr. Scott at once recognised the fundamental principles necessary for the successful solution of the problem in hand, and, on the strength of his recommendation, the writer's method of casting and conveying pig-iron was adopted by the Carnegie Steel Company.

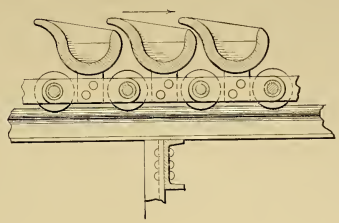


FIG. 11.—A SECTION THROUGH THE MOULDS OF THE UEHLING MACHINE

The company at once secured an option on the right to use the casting machine, and after satisfactory preliminary tests with a temporary machine, they secured the rights and at once proceeded to develop the invention. This task, which was by no means an easy one, was undertaken by Mr. Scott with all the energy and push and practical experience which are so characteristic of the man.

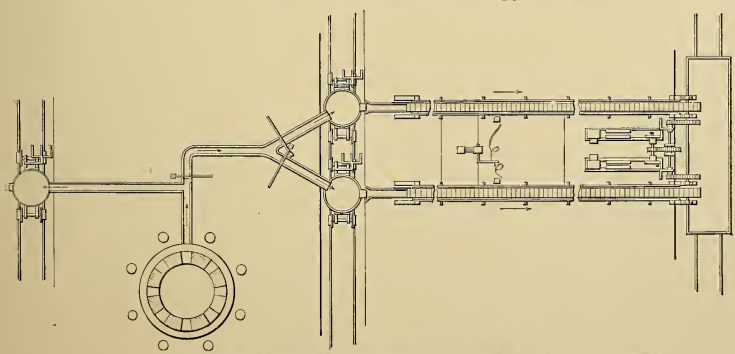


FIG. 10.—ORIGINAL DESIGN OF THE UEHLING CASTING MACHINE. PLAN SHOWING SECTION THROUGH HEARTH OF FURNACE

A machine capable of taking care of the total product of the Lucy furnaces, —750 tons per day,—was designed and erected inside of two months. This

machine, though fully coming up to Mr. Scott's calculation as to capacity, and in every other way demonstrating the practicability of the method, showed many troublesome deficiencies and weaknesses, and, in less competent hands, and supported by less powerful backing, would probably have proved a temporary failure.

The word failure, however, does not occur in the vocabulary of Mr. Scott's dictionary, and the Carnegie Steel Company would have given it no recognition if it had. A second machine was, therefore, at once designed and constructed in which all the weaknesses and deficiencies were corrected. This machine was a complete success from the start. It is in operation to-day, and has taken care of the total product of the two Lucy furnaces since March, 1897.

Figs. 10 and 11 are reproduced from patent drawings of the Uehling casting machine, the invention of which took concrete form early in 1894, and for which application for a patent was made on November 24 of the same year. This was granted and issued on October 15, 1895.

The scope of the invention is sufficiently indicated by the first and seventh claims, which read as follows:—

First.—The herein described method of casting pig metal which consists in collecting the metal from the furnace in a reservoir, bringing said reservoir into communication with an endless connected series of moulds, pouring the metal from the reservoir in a controllable continuous stream into said moulds, and moving the latter continuously at such a speed that they will be uniformly filled, automatically and continuously deliver the pigs at the opposite end, and *continuously injecting refractory material into the empty moulds* as they return to be filled with moulten lead.

Seventh.—For casting pig iron a plant having arranged side by side two or more independent series of connected moulds forming endless casting platforms, the moulds whereof have their contiguous edges over-lapping and are mounted upon rolling supports, fixed ways for such supports, a spout at one end of each set of moulds, a blast furnace and reservoirs communicating between the mould carriers and blast furnace, a driving mechanism in connection with each set of moulds, an engine and mechanism for connecting it to the driving gear of the said set of moulds, *a reservoir for containing a mixture of refractory material and spraying devices for the refractory material for operation substantially as described.*

The portion of the claims given in italics are the vital points necessarily embodied in every machine in which pig-iron can be successfully cast. An automatic spraying device was not shown or described in this patent, for the reason that it was thought best to make it the subject of a separate patent after practical experiments should have demonstrated which of the several methods should prove most effective.

Rarely did an invention attract so much attention as the casting machine. Furnace men, furnace builders, metallurgical engineers, and others from far and near took advantage of the liberality of the Carnegie Company, who gave free access to anyone interested to see the machine that so successfully and completely overcame the cast-house troubles. Many went because they did not believe it could be done; more of them went because they were glad that it was being done; and some of them went to see if it could not be done some other way.

That the casting machine was destined to become an accessory to every blast furnace plant producing over 100 tons of iron per day was evident to all who were acquainted with the difficulties and troubles inseparable from the old method. It is, therefore, of little wonder that no sooner had the machine at the Lucy furnaces demonstrated the practicability and economy of handling the output of the blast furnace mechanically than casting machines, differing more or less from the Uehling apparatus and from one another, sprang up as by magic in all quarters.

The Lucy furnace machine proved itself to be a veritable egg of Columbus. The thing was so easy; really there was nothing new about it. Iron had been tapped into ladles and other receptacles from cupolas and furnaces and transported to and poured into moulds long years before. Then the endless series of moulds or buckets moving in continuous procession,—why, that is a device as old as the Pyramids; it was used by the old Egyptians to raise water for irrigation a thousand years before the Christian era. The only thing really new about the whole machine was the idea of continuously coating the moulds with refractory material, and anybody could have thought about that. Anyway, that can be got around by doing

it a little differently. Since the successful demonstration of the casting machine at the Lucy furnaces about twenty or twenty-five patents have been issued to real and would-be inventors of casting machines, of which two stood the practical test, and will be more fully described further on.

It is far from the writer to say one word of discouragement to those who, by choice or necessity, take up ideas second hand, as it were, and work them out on new or modified lines, or improve on existing methods, machines or appliances with the honest purpose of improving on them, that is, to simplify construction and reduce cost, or to increase durability or efficiency, or all these together. Such action is not only perfectly legitimate, but highly praiseworthy. The act, however, of seizing upon practical inventions that fill an important want and even have had their commercial value proven by practical demonstration, more or less costly, simply by doing it more or less differently, or engrafting upon them modifications often quite the reverse of real improvements for the sole purpose of gaining thereby some notoriety, is quite another matter.

These manifestations of human weakness would be of little consequence were it not for the fact that financially strong, but morally weak, individuals and corporations are continually casting about for such second-hand inventions, often employing a corps of draughtsmen to produce them, for the sole purpose of getting around paying a legitimate royalty.

That concerns governed by a far-sighted business policy and directed by men of practical experience work on broader lines, is illustrated by the part played by the Carnegie Steel Company in developing the casting machine.

It is a noteworthy fact that the first to adopt the casting machine under a royalty to the Carnegie Company was the Struthers Furnace Company, who operated one of the smallest, but best conducted furnace plants in the Mahoning Valley. Figs. 12 and 13 illustrate this machine; it was put in operation in July, 1897, and has never failed to take care of the product of the furnace, which varies between 250 and 300 tons per day. The repairs to this machine have been very light. The moulds have the remarkable record of carrying on an average nearly 340 tons, or 6800 fillings. This record is probably exceptional, and is attributable to the care taken to have the refractory material of the proper consistency and the spraying device always in good order. All the moulds are cast direct from the furnace at a cost of less than forty cents apiece.

The second casting machine was contracted for by the Carrie Furnace Company, the smallest double-furnace plant in the Pittsburgh district. This plant was subsequently bought by the Carnegie Steel Company and quadrupled in its capacity, and the machine was, therefore, remodeled and enlarged, to meet the greater output.

A very close account kept at the Lucy furnaces of the cost of labour, wear and tear on machine, refractory material, oil and waste, power, interest on plant, etc., showed that there was an actual saving in favour of the machine over the cast house of a fraction over 10 cents a ton. Very conservative estimates, based on the saving of fuel and flux in remelting, as well as quicker work, less wear and tear on cupola and open-hearth furnace, due to the sand attached to the cast-house pig, less labour, because of reduced amount of flux and slag to be handled, etc., showed the minimum saving to be about 10 cents in the cupola and at least 25 cents a ton in the basic open hearth. An average saving, therefore, of 10 cents at the blast furnace and at least 15 cents in the steel works, or 25 cents per ton in all, which, based on a furnace of 300 tons daily capacity, amounts to over $25,000 per annum.

Satisfied with the results obtained at the Lucy furnaces, no time was lost in putting in a six-strand machine at the Edgar Thompson furnaces (Fig. 15), and also a double machine at Duquesne. These machines were soon in operation, and the Carnegie Steel Company was reaping the demonstrated

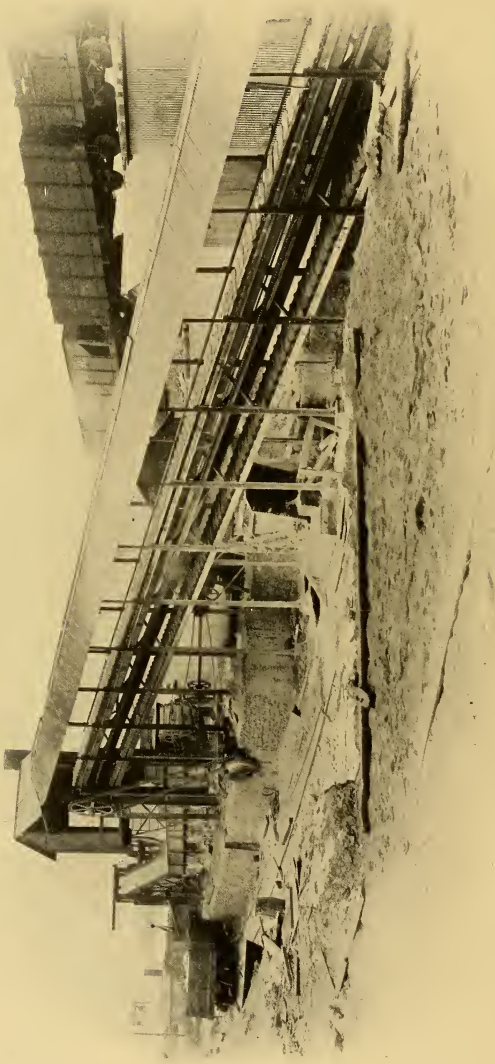


FIG. 12.—A SINGLE-STRAND UEHLING CASTING MACHINE INSTALLED BY THE STRUTHERS FURNACE COMPANY, AT STRUTHERS, OHIO. LOOKING TOWARDS THE DELIVERY END

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benefit, viz., 25 cents per ton of iron cast and converted into steel.

Meanwhile, many of their large competitors were experimenting in more or less elaborate and costly ways how to get around paying a royalty, which for the life of the patent would not equal three mills per ton of iron produced. The results of these attempts proved in every case unsuccessful, and the cost exceeded by far the royalty asked.

Regarding the present state of the art of the pig-iron casting machine, it would be going beyond the limitations of this article to take it up exhaustively. So far as the undeveloped machines are concerned, let it suffice to say that since the advent of the Uehling machine no less than twenty-three patents on devices to accomplish the same purpose have been issued. Of these, so far as the writer is aware, seven were put to a practical test and two survived. These two, the Patterson & Vaughn, known as Heyl & Patterson machine, shown in Figs. 16 and 17, and the Davis & Croxton, known as the Davis machine, shown in Fig. 18, were consolidated with the Uehling interest, and are now controlled in the United States by the American Casting Machine Company, of Pittsburgh. These three types of machines differ considerably in arrangement of the moulds and construction of detail, but they have in common the vital principles which are set forth in the claims of Uehling's patents, and without which pig-iron cannot be successfully cast over a machine.

The Uehling casting machine has been so frequently and fully described that it will not be necessary to do so here. Its reliability and wearing qualities have already been alluded to. It may only be stated here that the wear and tear in any machine, and especially in a machine of the class to which the casting machine belongs, is inversely proportional to the intelligent care bestowed upon it. There is, therefore, absolutely no reason why the results obtained at the Struthers furnace should not be duplicated by every Uehling casting machine in use, provided its capacity is not overtaxed.

The Heyl & Patterson machine (Figs. 16 and 17) gives evidence of marked originality of conception, and of much courage in the practical application of the ideas embodied in this machine by its inventors. Their object appears to have been to simplify and cheapen the construction of the machine.

To accomplish these ends the cooling trough is made part of the casting machine proper, and the mould with its contents is immersed immediately after filling and carried under water a distance sufficient to cool the pigs. The tracks then incline upward to permit the discharge direct over an adjustable chute into gondola cars. By this means the separate cooling trough and plate conveyor employed in the Uehling machine are dispensed with.

The moulds are made of pressed steel, since cast iron would not stand the sudden chilling. The chain construction is much simplified by the type of link employed, and by placing two moulds on one link. The moulds are coated with carbon by passing them over a smoky coal fire before returning to the point where they are again filled with iron. The design of the machine was ably worked out. It is substantially built, has fewer wearing parts, and takes up very much less room than either of the other two machines.

The principal features embodied in this machine are:—

1.—An endless series of moulds, of which two are mounted on one pair of links, which are carried by a pair of flanged wheels, running on fixed rails, and rotating about a common axis of a length greater than that of the moulds.

2.—The moulds are made of heavy sheet steel under a hydraulic forming press, and overlap one another.

3.—The moulds are filled from a continuous, controllable stream of iron, and immediately pass into a suitably arranged tank of water, in which they are first partially and then completely submerged with their contents of molten metal. The length of the tank is calculated to be sufficient to solidify and cool the iron.

4.—At the end of the cooling tank

FIG. 13.—THE POURING END OF THE STRUTHERS FURNACE COMPANY'S MACHINE

the wheel track inclines upward to a height sufficient to discharge the pigs over an adjustable chute into the gondolas or other cars placed there to receive them.

5.—On their return trip the moulds are carried over one or more furnaces in which a smoky fire is maintained. The soot contained in the products of combustion, *i. e.*, the refractory material, is injected into the moulds by the force of the draught, and, under favourable conditions, adheres sufficiently to form a refractory coating which effectively prevents the molten iron from welding fast to the moulds. The latter, thus coated, pass again under the stream of iron, are refilled, and continue in their course until the supply of molten iron has all been delivered into the cars in the form of pigs ready for shipment to destination.

It is evident that, with the exception of the general arrangement and the cardinal principles developed and practically demonstrated in the Uehling casting machine, Messrs. Patterson and Vaughn proceeded on lines both original and radical, and deserve much credit for the ingenuity, perseverance and courage manifested in the development of their machine.

The Davis machine (Fig. 18) differs very materially, both in general appearance and detail of construction, from both the Uehling and Heyl & Patterson machines. It consists of a large horizontal wheel which rotates about a fixed centre. Two concentric rings of channel bars, supported by radial arms at their outer ends, carry the moulds, which are supported by trunnions in bearings and provided with means for overturning them at the proper time and place.

The moulds are filled from a controllable stream, and the iron is permitted to solidify before dumping the moulds. The red-hot pigs fall on a plate conveyor running on tracks underneath the moulds, so arranged that the pigs are carried under water a distance sufficient to cool them and then deliver them over an adjustable chute into cars ready for shipment. The moulds are coated with refractory ma-

terial dissolved in water and sprayed into them by gravity.

The principal points of the Davis machine are:—

1.—An endless series of moulds, attached to the periphery of a large turntable in such a manner that they may be automatically overturned to discharge the pigs.

2.—The moulds are made of cast iron and provided with trunnions about which they turn. This feature makes it impossible for the moulds to overlap one another, and necessitates a deflecting piece to be placed over the crevice between each pair of moulds to prevent the iron from running to waste between them.

3.—The iron is run into the moulds in a continuous, controllable stream, and is retained in them a sufficient time to solidify. The number of moulds and their speed of travel is so gauged that this is effected when the moulds arrive at the point where the pigs are discharged.

4.—At the proper time and place the moulds are automatically inverted, discharging the pigs on a plate conveyor which travels directly underneath and in unison with the moulds, carries the pigs through a tank filled with water and delivers them, practically cold, over a properly arranged chute into a gondola or other car placed to receive them.

5.—Immediately after dumping out the pigs, the moulds pass a spray of refractory material which coats them sufficiently to prevent the iron from welding fast to them. The moulds, thus properly coated, continue in their course, and are again filled, etc.

FIG. 14.—DELIVERY END OF A UEHLING CASTING MACHINE, SHOWING THE WATER-COOLED CONVEYOR

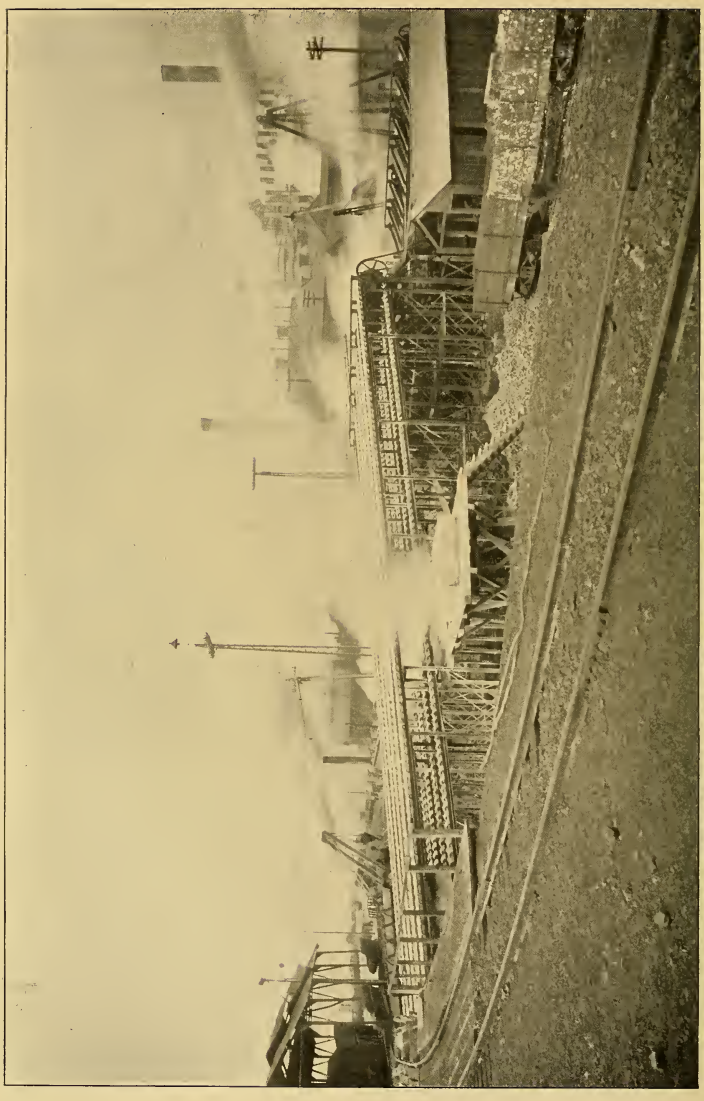


FIG. 15.—A SIX-STRAND UEHLING CASTING MACHINE AT THE EDGAR THOMPSON STEEL WORKS

Each of the three successful casting machines here described has its advantages and disadvantages. The Uehling machine is the best machine of the three in so far as it will successfully cast all the different kinds of iron produced, and can be adapted to take care of any quantity of iron that it may be necessary to handle. Its first cost is higher than that of the Heyl & Patterson machine for equal capacity, and it takes up about double the room. As heretofore constructed, the greatest drawback to the Uehling machine was the wear and tear of the many links, pins, and rollers of the mould chain, which could not be effectively protected against the splashing and spattering of the molten metal, unavoidable in pouring, and could be properly lubricated only with difficulty.

These drawbacks the writer hopes to have overcome completely by his new self-lubricating and rolling-joint mould chain. A further very important improvement in the latest Uehling machine consists in the construction of the mould and the arrangement of the pouring end in such a manner that the overflow of the mould receiving the iron passes into the next mould following, thus avoiding all scrap due to irregular pouring, through negligence or other causes.

The Heyl & Patterson machine has in its favour two very important features which have given it almost exclusive right of way in all such works where all, or nearly all, the furnace product is converted into steel direct, and the machine is utilised for the Sunday iron principally. These are, first, that for equal capacity it is materially cheaper in first cost, and, second, requires much less room than either the Uehling or the Davis machine. It has other advantages which, though often more apparent than real, have, nevertheless, been a large factor in deciding which machine to adopt, it being tacitly understood that either of the three machines are equally available, and that it is quite immaterial, so far as the American Casting Machine Company is concerned, which is adopted.

The Heyl & Patterson machine was a well-designed and substantially built machine from the beginning. The mould chain construction, which, by placing two moulds on one link, reduces the number of joints to one-half, and other points of excellence appeal to the mechanic. The pressed steel mould also makes a good first impression.

The greatest drawback to the Heyl & Patterson machine is due to the necessity of submerging the moulds, as well as their contents, under water immediately after filling. This produces stresses due to sudden and unequal contractions which no known material can long withstand. The moulds begin to warp and buckle and soon become useless either from distortion or cracking. In passing through the water the moulds also become wet inside as well as out, and frequently arrive under the pouring spout with sufficient moisture in them to cause explosions which are always annoying and often dangerous, and throw out considerable quantites of iron, producing an excessive amount of scrap.

The fact, however, that this scrap can be directly utilised in the open-hearth furnace or cupola, and that six days out of every seven are available for cleaning up and replacing warped moulds, minimises these defects to such an extent that the advantages above stated apparently more than overbalance the drawbacks, in the judgment of the large steel manufacturers. This is evident from the almost general adoption of the Heyl & Patterson machine at those works.

The Davis machine has the advantage over the other two in having very much fewer wearing parts. Its first cost is about the same as that of the Uehling machine of equal capacity. It has the great disadvantage that its capacity is limited, and that it requires more room than either of the other two. The moulds are very heavy, and should have a greater life even than those of the Uehling machine. They also have the advantage of the latter in so far as they can cast direct from the furnace with no further cost than the labour of moulding and cleaning up. The old moulds go back to the furnace and

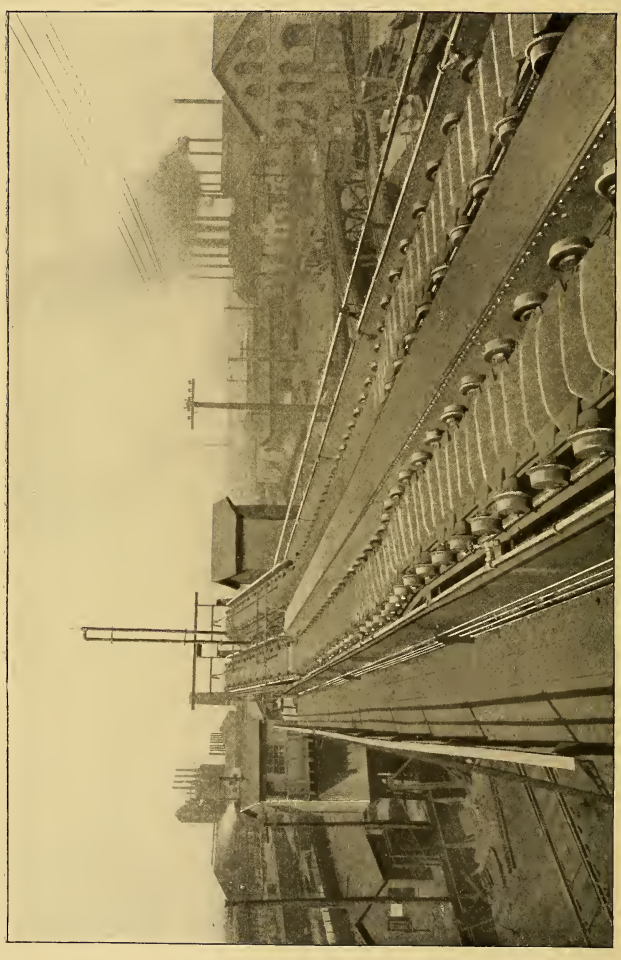


FIG. 16.—PIG-IRON CASTING MACHINE MADE BY MESSRS. HEYL & PATTERSON, OF PITTSBURGH, AT THE WORKS AT JOLIET, ILL., OF THE ILLINOIS STEEL COMPANY. LOOKING TOWARDS THE DELIVERY END

are remelted at an insignificant expense. The Davis machine, as well as the Uehling, can successfully handle all classes of iron produced in the blast furnace, because the iron does not come in contact with water until it is completely solidified and practically cooled; and, if necessary, cooling by immersing can be entirely dispensed with. Low-silicon iron, that is, iron containing less than one-half of one per cent. of this constituent, does not bear sudden cooling without breaking up badly. If, in addition, it contains a high percentage of phosphorus, as is necessarily the case with basic Bessemer iron, sudden cooling is absolutely prohibitive, since it causes the iron to break into fragments varying from the size of a man's fist to a walnut, to which most of the objections that proved fatal to Scott's granulating process apply with equal force. Spiegel and ferromanganese, particularly the latter, behave in a similar manner.

In the Heyl & Patterson machine immediate immersion is indispensable to successful operation, and this limits its application to the class of iron which will bear sudden cooling. Fortunately, the greatest part of the iron produced in the United States will stand this treatment; the same is true in Great Britain. Only a small portion of the iron produced on the Continent of Europe could be handled with this machine. In all installments of the Uehling machine on the Continent even the comparatively moderate water cooling after solidification had to be omitted.

In conclusion, a few words regarding the general attitude of the producers and users of the foundry iron towards the casting machine and the iron cast in it. That the adoption of the casting machine at furnace plants producing iron for steel making has been practically universal is due to three causes:—

First.—The enormous outputs of the modern blast furnaces cannot be handled economically, if at all, by hand.

Second.—Sandless iron, produced by the machine, is far superior for smelting either in cupola or open-hearth furnace.

Third.—Grading iron by fracture is

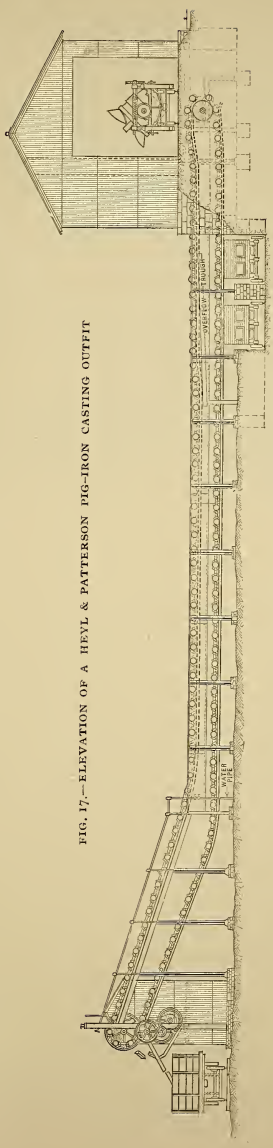


FIG. 17.—ELEVATION OF A HEYL & PATTERSON PIG-IRON CASTING OUTFIT

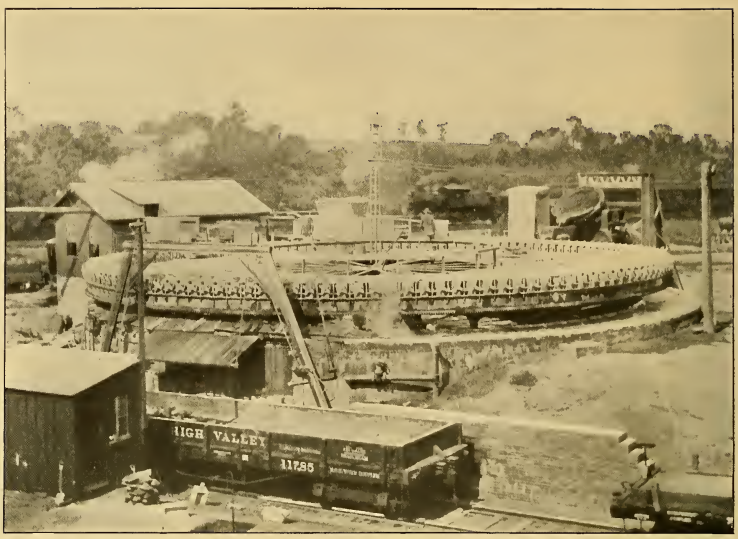


FIG. 19 THE DAVIS CIRCULAR CASTING MACHINE AT THE WORKS OF THE BETHLEHEM STEEL CO., SOUTH BETHLEHEM, PA.

obsolete, and analysis is entirely depended upon by steel makers.

While a large percentage of foundry iron is already bought on analysis, especially by the larger consumers, the bulk of it is still selected entirely on the appearance of the fracture. For the small consumers, who, in the great majority of cases, lack the scientific training to understand and practically apply the information given by chemistry, there is a very good excuse for adhering to the old system, in so far as it gives them at least some tangible basis for judging their iron before putting it into the cupola. For large consumers there exists no such excuse. If they do not know enough themselves they can readily employ someone who does, as well as give him the necessary equipment and opportunity to apply in practice the rational deductions of science.

This is already done by many; but it is a curious fact that the majority of those even who fully understand and appreciate the value and adequacy of chemical analysis, and know the uncertainty and misleading tendency of judging the quality, and particularly the fitness, of the iron for the work in hand by the appearance of its fracture, still insist on classification by fracture in addition to chemical analysis.

Much could be said on the shortsightedness of insisting on fracture, as well as analysis, by those who know that the latter is and that the former is not a reliable guide to the value of pig-iron. The writer will mention only one phase of this subject in so far as it relates to machine-cast pig-iron. That there is a saving in fuel, flux, wear and tear of cupola, etc., of about 10 cents a ton in remelting machine-cast over sand-cast iron has already been mentioned. That the machine-cast iron is more homogeneous, because of the mixing it gets in the ladles, and also that an appreciable amount of desulphurisation takes place in the ladle, the writer would mention only in passing, and would conclude with the following conversation

that took place between the writer and the proprietor of a blast furnace producing foundry iron for the market:—

"I see you are still casting in the sand. Would it not be profitable to have a casting machine?"

"No; not considering everything."

"How is that? The machine will certainly handle your iron cheaper than you can do it by hand; besides, you get rid of the labour difficulties on cast beds, etc. I should think that alone would be sufficient inducement to install a machine?"

"That is all very true; but we make principally foundry iron, and our customers judge the iron by fracture. What would be Grade No. 1 in the sand would be No. 3 over the machine, and would bring a correspondingly lower price, which, as you know, is based on the present system of grading."

"Yes; but the present system of grading is a poor guide at best, and since you already analyse all your iron, why not sell on analysis altogether, in other words, educate your customers to the standard of judging the iron by analysis?"

"That would be a thankless undertaking; besides, it pays us better to sell sand iron. We allow twenty-eight pounds per ton for sand; the iron actually carries nearer fifty. This excess of sand, for which we get $20 a ton, much more than overbalances the saving that could be effected by using the machine, so that it would be bad economy on our part to install a casting machine so long as the consumer insists on an open fracture, irrespective of analysis, and is willing to pay us pig-iron prices for the sand."

This is certainly food for thought for the consumer of foundry iron, whether he insists on grading iron by fracture, because he knows no better way, or because of the doubtful advantage to be gained by complaints on account of fracture, though the analysis be correct. The effect on the pocket-book is the same. To pay pig-iron prices for sand, which costs freight, additional fuel, more flux, and increased wear and tear on cupola, can hardly be conducive to increased dividends.

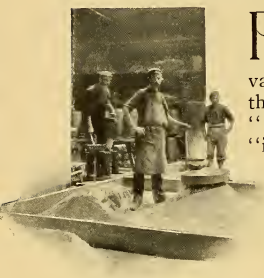
The casting machine, considered from the standpoint of the engineer, is destined to perform two important functions, namely, that of relieving the labour of a most arduous task and that of reducing the cost of production. In its relation to the manufacture of steel it is already performing both functions in a marked degree; whereas, in its relation to the foundry, it still lacks intelligent appreciation on the part of the consumer.

In so far as it should, and by virtue of these functions necessarily will, in a measurable degree assist in elevating a most important industry out of the deep rut of the "rule of thumb" to the high plane of applied science, it will perform an additional function even more important than the other two. And what is true of the casting machine is equally true, in a greater or less degree, of all, or nearly all, labour-saving appliances.

THE ADVANTAGES OF MACHINE-CAST PIG-IRON

By Albert Ladd Colby, Metallurgical Engineer of the Bethlehem Steel Company

Mr. Colby's summing-up of the advantages of machine-cast pig-iron is of especial interest here in connection with the preceding article dealing with the development of the machinery employed in its production. The remarks are extracts from an address made by Mr. Colby a short time ago before the Philadelphia Foundrymen's Association.—THE EDITOR.



PIG-IRON cast in iron moulds is known by various names in the trade, such as "chilled pig-iron," "iron cast in chills," "machine-cast pig-iron," "machine-made pig-iron," "sandless pig-iron," "sand-free pig-iron," etc. In the older method of casting pig-iron in sand, the stream of iron coming from the furnace and passing down the centre of the casting house is turned to fill the first row of sand moulds, usually located at the far end of the casting house, although at some furnaces the bed nearest the furnace is filled first. When one row or bed of moulds is nearly full, a gate is opened and the iron passes from the central "runner" into the second row, and so on, until the cast is completed. The main stream is called the "runner"; the feeder to each row or "bed" of moulds is called the "sow," and the sand moulds branching off from the "sow" are the "pigs."

No one can be about a blast furnace very long without having brought forcibly to his notice the difficulties attending the casting of pigs in sand. Furnaces sometimes smelt and reduce the ore irregularly, so that there are always times when the casting house is hardly cleared ready for another cast before the furnace should be again tapped. This is especially true if the skimmer has been washed away in the previous casting, and much of the iron covered over with a mass of cinder, so that the work of breaking up the hot iron and carrying it out of the casting house has been unusually hard. Work on the hot pig beds is severe at best, and there is always trouble getting labourers to stand this heavy work with its rapid changes of temperature, especially as it means work every day in the year, including Sundays and legal holidays.

With a small product of, say, 100 tons per day, the casting of pigs in sand is not so serious a matter; but some better method of casting became absolutely necessary with the modern furnaces with a daily output of 300 to 500 tons, or even more. As Uehling says,—"Necessity is the mother of invention, and the casting machine came into existence through sheer necessity, not to say desperation."

The advantages of machine-cast pig-iron to the makers of basic open-hearth steel are now universally recognised. The number of basic open-hearth furnaces receiving molten iron from a mixer, or direct from the blast furnace, or in some cases from a cupola, is on the increase. In cases where the iron is charged as pigs, the machine-cast iron is always called for, and sand-cast basic iron is accepted only at a reduced price. With a machine-made iron there is no sand to attack the basic furnace lining. The higher proportion of combined carbon in the chilled iron makes the iron melt more rapidly, and as the combined carbon unites during melting more rapidly with oxygen than the graphite does, the bath when melted is lower in carbon than when using sand-cast iron, and hence more quickly converted into steel.

These advantages, in brief, mean less fuel and increased output.

In puddling furnaces the machine-cast iron is also more advantageous than the sand cast iron. The variable quantity of silica, with a little alumina added to the bath in the form of sand adhering to the sand-cast pigs, causes irregularities in the basicity of the puddling cinder, and hence irregularities in the amount of phosphorus and sulphur removed. With machine-cast iron the basicity of the puddle cinder is governed more closely by the silicon in the pig-iron and the silica in the "fix," causing greater uniformity in the composition of the cinder, which, in turn, gives more uniform product, and tends to prevent sudden and irregular cutting of the furnace linings. The increased proportion of carbon in the combined state in the machine-made iron is likewise an advantage, as the puddling operation is thereby shortened without detriment to the product.

In the use of Bessemer pig-iron and of low phosphorus pig-iron, whether melted in the cupola for the Bessemer converter or melted in an acid open-hearth furnace, the same advantages result by the use of machine-cast iron as have already been outlined above.

As to machine-cast pig-iron for foundry use, the purchaser of such iron will receive 2240 pounds per ton of iron shipped; there can be no dispute about short weights, and that abomination, the "sand ton" of 2268 or 2256 pounds per ton is abolished. The amount of sand adhering to iron cast in sand varies greatly. When the iron is loaded directly from the casting bed and has only a short haul to the foundry, the sand on the pigs is excessive. If loaded from stock and hauled a considerable distance, more of the sand shakes off before the pigs reach the cupola platform; but at best that remaining is a detriment, and frequent cause for dispute in weights and an expense in melting.

In-melting machine-made iron the founder will find that he uses less limestone, and that, therefore, less slag is produced. This means less fuel to dissociate the carbonic acid gas in the flux and less fuel to melt the smaller amount of slag produced; also less loss of iron in the slag. The machine-cast iron also melts easier,—an item which gives a further saving in fuel. The melted iron is cleaner, contains no dross, and that frequent cause for defective work, "dirty iron," is absent. Another advantage of machine-cast iron is that the pigs of the cast are more nearly alike in chemical composition than pigs of a cast of iron run from the furnace into sand; and, furthermore, there is a greater uniformity in the different parts of a machine-cast pig than in a sand-cast pig. This greater regularity of the different parts of a cast is due to the fact that the furnace is tapped into 20-ton ladles, and the iron is thus mixed before casting the pigs. These are more uniform in composition, because they solidify more rapidly in the iron moulds of the casting machine, and hence there is much less time for the impurities to segregate toward the top and centre of each pig.

The writer has met with four objections made by foundrymen to iron cast in chills, whether in the metal moulds substituted for the beds of sand in the casting house or the moulds of the casting machine.

1.—The prejudice against all machine-cast iron, due to the sale of some sandless misfit basic pig-iron for foundry purposes.

2.—The large size of the machine-cast pigs.

3.—The close-grained fracture as compared with the fracture of sand-cast iron.

4.—The difficulty in drilling the pigs for analysis.

1.—There is a well-grounded prejudice to machine-cast pig-iron, owing to the sale to foundrymen of misfit basic iron cast in chills, which, although perhaps high enough in silicon, is also often high in sulphur. Doubtless in many cases this iron had not the best analysis for the purpose for which it was sold to the foundryman. It was, perhaps, too high in sulphur, and very likely too low in total carbon for the kind of casting into which it was made. The unsatisfactory result attending its use has given

a bad name to all machine-cast iron in general, and has prejudiced the foundryman against its use. This is unjust to those furnaces making first class machine-cast foundry iron, but the prejudice is not to be wondered at; it can be overcome only by a straightforward explanation of the facts, and by giving a guaranteed analysis of the standard machine-cast foundry pig-iron offered.

2.—The large size of the pigs of machine-cast iron has been objected to. Some of the casting machines make a large pig, too heavy to conveniently handle on the cupola platform, and too large for economic melting in small cupolas. There are machine cast pigs, however, weighing not over 90 pounds each, and of such a shape as to be readily broken if destined to be melted in very small cupolas.

3.—The main stumbling-block to the introduction of machine-cast pig iron in the foundry is the appearance of its fracture; its looks are against it. There are two ways of meeting this objection. First, by proving to the foundryman that the machine-cast iron, although having a close-grained fracture, will make, if it has the right chemistry, as soft and as easily machined a casting as an open-grained sand-cast pig-iron of the same analysis.

The close-grained fracture is due to the quick cooling and to the temporary conversion of considerable of the total carbon into the combined form, with a correspondingly temporary reduction of the percentage of graphite. The change of carbon is caused by the chilling action of the iron moulds of the casting machine, and the further and deeper chill caused by the sudden cooling of the hot pig by immersion in a bath of water. This difference in the proportion of combined carbon is illustrated by the following analysis of a cast of iron, one portion of which was cast in sand and another portion in the casting machine:—

	Sand-cast Per Cent.	Machine-cast Per Cent.
Combined carbon	0.250	0.920
Graphite carbon	3.210	2.460
Total carbon	3.460	8.380
Silicon	3.00	2.99
Manganese	0.95	0.95
Phosphorus	0.770	0.773
Sulphur	0.041	0.041

The increased percentage of the combined carbon, the uniform close grain, and in some cases the increased density of the machine-cast pig-iron, give higher tensile strength on specimens cut from the chilled pigs than on those cut from the sand-cast pig. This increased tensile strength is misleading, for it exists only in the pig itself. When both the machine and sand-cast pigs of the above cast were remelted separately in a cupola and cast into similar sized test ingots, standard test specimens threaded on each end and of an area at point of fracture of 1 square inch, gave the following results:—

Standard U. S. Army Test specimen cut from—	Tensile Strength. Pounds per Square Inch.	
Machine-cast pig	41,000	
Sand-cast pig	25,000	
	Cast Vertically	Cast Horizontally
Test ingot cast from machine-cast pig	17,000	17,000
Test ingot cast from sand-cast pig	16,300	18,000

Castings made at the same time as the above test ingots from remelted sand and remelted machine-cast iron were machined with equal ease, and showed similar fractures. The following analyses show that the excess of combined carbon in the machine cast pig disappeared after remelting:—

	Carbon		
	Combined	Graphitic	Total
Sand-cast pig	0.250	3.210	3.160
Machine-cast pig	0 920	2,460	3.370
Test ingot cast by remelting sand-cast pig—			
Cast vertically	0.368	3.022	3.390
Cast horizontally	0.470	2,930	3.406
Test ingot cast by remelting machine cast pig—			
Cast vertically	0.257	3.100	3.357
Cast horizontally	0.336	3.028	3.364

Another practical illustration of the fact that the chill in the pig-iron does not reappear in the casting made from it, if the chemistry is right, is the use of old chilled iron car wheels by foundrymen. At one time when old car wheels were cheap the writer knows of an instance where 5000 tons were purchased by a maker of cast-iron pipe. The wheels showed a deep chill, but the chill did not show in the pipe. The wheels made strong pipe, but it was uniformly gray in fracture, and contained no hard or chilled spots.

The second method of meeting the objections of the appearance of the frac-

ture of machine-cast iron is to submit to the foundryman facts showing how often the appearance of the fracture of sand-cast iron is misleading, and prove to him that chemistry is the only safe guide to uniform success in the foundry.

The writer does not mean that the foundryman can safely ignore the fracture of sand-cast pig-iron if he does not include the total carbon in his chemical specification, especially if he must make very soft castings; but he does mean to have it understood that if the foundryman specifies the correct silicon, sulphur and total carbon, with possibly manganese, desired, that he can safely ignore the appearance of the fracture.

Among the advantages claimed for machine-cast iron some have made the statement that the appearance of the fracture of machine-cast iron is a safer indication of its quality than with sand-cast iron. The value to the furnaceman of the chill cup test, used at some furnaces as an indication of the sulphur and silicon contents of the pig, is cited in illustration of the above statement. The writer thinks, however, that it will be found in actual practice that the fracture of machine-cast pig-iron, especially from different furnaces, is an unsafe guide, and should not be depended upon by the foundryman as a substitute for the chemical analysis.

4.—The fourth objection which the writer has heard made about machine-cast iron is the difficulty in drilling the pigs for analysis. This brings up the general question of how to sample pig-iron.

With the more general incorporation of chemical specifications in contracts governing the sale of pig-iron for all purposes, the question of how to determine whether the shipper has lived up to his contract becomes more important. If seller's and buyer's chemists do not agree, the first step should be an exchange of samples to check accuracy of analytical methods; in some cases the service of a reference chemist will be required. Such a test is just only when the sample drillings are ground and thoroughly mixed, and when a sufficient quantity for duplicate analysis is distributed to each chemist. Marked differences between the furnace analysis on which the casts of pig-iron are selected for shipment on a certain contract and the report of the buyer's chemist on the cars of iron received will more often be due to improper sampling of the iron than to inaccurate analytical work. Everyone knows of the unavoidable variations in the chemical composition of different parts of a cast of sand-cast pig.

The furnaceman must consider each cast of iron as a unit, and should spare no pains or expense to obtain a sample representing the true average of the cast. He cannot honestly claim to have done this unless he has taken four, or preferably six, samples of the molten metal during casting; when the casting machine is used, the sampling can best be done as the large ladles of iron are being emptied into the moulds by filling a small test ladle at stated intervals. If these test ladlefuls are cast into small ingots, the sample analysed should consist of an equal quantity of drillings from each of the four or six ingots; if each small ladleful is poured into water, the same number of shot from each sample should be pounded together to make the average sample of the cast. In filling an order the furnaceman must consider each cast as a unit, and select those casts for shipment of which the furnace analyses fall within the customer's specification. As cars vary in size, and as the railroads always insist on having them loaded to nearly their full capacity, it is impossible to ship each cast of pig-iron separately, for it may weigh less, but more often considerably over the capacity of the car; the best the furnaceman can do, therefore, is to load casts of similar silicon and sulphur contents on the same car.

It is obvious that the customer's chemist when sampling the iron must consider each carload as a unit, and from what has been said it would be manifestly unfair for him to condemn a car of iron on the analysis of drillings from only two or three pigs. A good routine method of sampling consists in selecting two pigs from the surface of the carload

of iron at points equally distant from each end of the car and two more pigs from the bottom of the car, preferably at different distances from the end of the car. These pigs should be broken and drilled in the fracture, preferably by the use of a wide-angle, blunt-pointed drill, 2 or 3 inches in diameter, using rather a slow feed, so as to obtain uniformly fine drillings. If this requires a larger drilling machine or more power than can be assigned to the task, a number of holes may be drilled in the face of each pig, using a smaller drill.

If the analysis of an equal portion of carefully mixed drillings from each of these four pigs shows a wide variation from the chemical specification under which the iron is purchased, the car of iron should not be condemned by the customer without taking a more thorough sample, consisting of a dozen, or better twenty, pigs selected from different parts of the car. The pigs should be selected arbitrarily, and no attention paid to the fracture. With sand-cast iron sold on a guarantee of 0.050 per cent. sulphur, a customer could unfairly condemn many cars shipped by selecting only the pigs showing the closest grained fracture, and by taking drillings for analysis with a small drill in the top part of each pig.

When the iron is machine-cast, the proper sampling of each car is a laborious undertaking. If low in silicon, the iron is so deeply chilled that the pigs can be drilled only in the centre, if at all; the presence of 1 to 2 per cent. of manganese also renders machine-cast iron very hard to drill. When impossible to drill, the reduction of chips of the chilled iron to a powder in a steel mortar is a slow operation, unless the laboratory is unusually well equipped for such work.

Without for a moment denying the right of the buyer to check the furnaceman's analysis, the writer believes that the furnaceman has a much better opportunity of determining, by conscientious sampling, the true average composition of each cast of iron, and he ventures to predict that with the more general introduction of machine-cast iron the customer will purchase iron from furnaces where proper care is used in sampling, and then rely, with only an occasional check, on the furnace analysis of the casts loaded on each car, which information should be given on cards tacked on the inside of each car, and also by postal advices of each day's shipment from the furnace.

This suggestion does not apply to the closer inspection necessary in some cases if the customer suspects that the furnaceman is shipping a little of his "misfit" iron at the bottom of each car of pig guaranteed as "standard." This dishonest practice, unfortunately carried on to some extent, is sure of detection, sooner or later, and is sure to react seriously on the reputation of this furnaceman's iron in the trade.

If several cars of the same iron are to be placed in one pile, in order to equalise the difference in the chemical composition of the carloads, the first car unloaded should be distributed horizontally and evenly throughout the length of the proposed pile, the second carload similarly on top of this, and so on. Then by using vertically downward from one end of the pile, iron will be obtained which will conform very closely to the average analysis of the drillings from each car.

The greatest advantage which will result by the general introduction on the market of machine-cast foundry pig-iron, in the writer's opinion, is that it will tend to hasten the day when foundry pig-iron will no longer be sold by grade, based on the appearance of the fracture, but will vary in price according to its chemical analysis, which is fair alike to producer and consumer.

PRACTICAL LIQUID AIR POSSIBILITIES

FOR REFRIGERATION AND POWER

By Dr. Carl von Linde

Ever since the appearance on the market of machines capable of producing almost any desired quantity of liquid air, the services likely to be rendered by this new medium have been talked and written about in a more or less extravagant manner, partly from ignorance and partly from desire for gain. Many claims have been made for it, which, like soap-bubbles, have vanished most disappointingly. Several points of timely interest will, therefore, be found in the following extracts from a recent address made before the Ice and Cold Storage Association, of London, by Dr. Carl von Linde. —THE EDITOR.

ONE of the claims made for liquid air was that it would be "the cold-producing medium of the future." Not only would the working of our modern refrigerating and freezing stores be accomplished by means of liquid air, but everybody,—the manufacturer in his workshop, and alike the agriculturist on his farm,—might, at trifling cost, procure a cool and pure atmosphere for himself. Considering that liquefied air, vaporising at atmospheric pressure, possesses a temperature of −191 deg. C., it is hardly a matter for surprise that, with such an energetic cooling medium in view, the problem of applying liquid air for refrigerative purposes is raised again and again.

In the consideration of the merits of any particular source of cold two points are essential,—first, the quantity of cold produced, *i. e.*, the number of heat-units eliminated per unit of time; and second, the intensity of the cold, *i. e.*, the temperature at which heat is removed.

The most important physical law relating to the production of cold is well known as determining that the expenditure of energy necessary for a certain amount of cold increases in direct ratio with the difference between the lower temperature (in the refrigerator) at which the heat is taken away and the upper temperature (in the condenser or cooler) at which heat is transferred to the cooling water or to the atmosphere. Now, if the refrigerative purpose be the production or the maintenance of a temperature only a few degrees below the freezing-point of water, then, according to the law referred to, it must be exceedingly irrational to employ liquid air, seeing that for its attainment we are compelled to descend to −191 deg. C. (−312 deg. F.).

Supposing that anyone had to provide a well for obtaining surface-water from a depth of 10 feet, it would be insane to sink a shaft down to 300 feet, to let the water run from its surface-level down this pit, and then to raise it to a height of 300 feet. But this exactly corresponds to the idea of persons recommending the use of liquid air as a substitute in all the refrigerating machines of to-day. If we were to work our ice factories, our cooling and freezing stores, and our other cooling plants by liquid air, the requisite expenditure would be from thirty to fifty times greater than that of our modern refrigerating installations.

In view of such a disproportion we must put the question whether any cases at all are conceivable for which the employment of liquid air appears suitable for the purposes of refrigeration. Here we may recollect, firstly, that the disproportion in question is based upon the considerable difference between the temperature of liquid air and the temperatures required from technical refrigerating plants. Hence, if there be found cases where the temperatures obtained by present cooling machines are insufficient, and where we are compelled to descend down to the very low temper-

ature of liquid air, then the large expenditure of work involved will not appear as being spent irrationally. Hitherto such a requirement has been felt only in scientific research laboratories. The high schools of the majority of cultured nations now possess machines for liquefying air, and use them more or less diligently for investigating physical and chemical phenomena. The future must reveal whether such scientists' work will produce results of a kind valuable for technical application and industry.

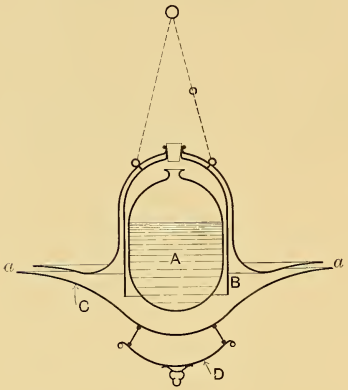


FIG. 1

But, setting the domain of lowest temperatures apart, various other applications of liquid air are conceivable for cooling purposes, *i. e.*, such cases where, firstly, relatively small quantities of cold are desired, and into which, secondly, there enter certain favourable properties of liquid air, such as the fact that it can be added to any body or to any chamber to be refrigerated without materially altering the same. I will mention a few such instances, but to facilitate understanding I am desirous of first submitting a short statement of the points which determine the storage and application of liquid air. It is frequently assumed that liquid air must be capable of storage and transit in steel bottles, as it applies to several other liquefied gases (ammonia, carbonic anhydride, nitrous oxide). This, however, is not so. For every liquefied gas there is a certain upper temperature above which it can exist only in the homogeneous gaseous state, even when subjected to a pressure however high. This "critical" temperature corresponds for ammonia to +130 deg. C., for carbonic anhydride to +31 deg. C., but for liquid air to −140 deg. C. As it is impossible to protect vessels so completely against the influx of heat as to maintain permanently in their interior this low temperature, it is consequently also impossible to preserve liquid air in a closed vessel. If we place it in a steel bottle and close the latter, the contents will, after a certain time, consist only of gaseous air of ordinary composition, and this under a pressure depending upon the quantity of air imprisoned. If the steel bottle has been entirely filled with liquid air, the pressure will have risen to about 800 atmospheres, provided that the vessel will not have flown into pieces previously.

Yet, notwithstanding this, we rightly speak of liquid air being preservable for days in proper vessels. For this we are indebted to Dewar, who caused glass vessels with double sides to be made, who had the air between both walls evacuated as far as possible to prevent the conduction of heat, and who provided one of the outer surfaces with a metallic mirror to reflect the impact of the external heat rays. The vaporisation of a comparatively small qantity of liquid air (say, one-quarter gallon) requires in such vessels about fourteen days; but they must, at the same time, always remain open to permit the escape of the gaseous air. Only thus will it be possible to maintain inside the bottle so low a temperature that the heat, however small in quantity, but constantly inflowing, will be spent upon a continual, though exceedingly slight, evaporation of liquid air. Any sealing of the bottles would be followed by their being burst. Such vessels, conveniently packed, are adapted for transporting small quantities of liquid air from a central station to any number of consumers within a certain radius, and can be used to establish

a sale similar to that of an ice factory. This has been actually accomplished at several places,—for instance, Berlin, Munich, and Antwerp.

What, then, are the applications for such liquid air? Scientific purposes again enter first of all into consideration. Further, this new article of commerce has commenced to be exploited in the direction of luxury and hygiene. I will mention some of these applications at the risk of their being viewed as trivialities. Only after some lapse of time will it be possible to determine whether they will prove of definite importance.

Whilst we already have had occasion to demonstrate why it is unreasonable to use liquid air for the refrigeration of stores, yet under certain conditions this agent may render excellent services for obtaining a local and limited cooling effect in a room. Let us picture to ourselves a sick-bed, a working-place, a writing-table, or also a dining-table, under circumstances rendering the atmosphere sultry and oppressive. There it is possible to create an exceedingly beneficial result by allowing comparatively small quantities of pure and cool air to descend slowly from a higher level.

Figs. 1 and 2 show two forms of an apparatus suitable for this purpose. The vessel *A*, Fig. 1, is filled with liquid air, which after a certain time will evaporate under the influence of the inflowing heat. The products of evaporation pass at first around the vessel *A*, simultaneously receiving heat from the wall *B* and transmitting the same in part to *A*. This absorption of heat is continued also after the air is passed into the tray *C*, with the result that air of a moderate temperature will issue from the openings *a a*. As long as this temperature remains very low, a precipitation of humidity from the surrounding air into which the cold air passes will ensue; this is avoided by the preliminary heating. The entire heat requisite for vapourising and heating the products of evaporation is eliminated from the surrounding atmosphere; hence, not only the former, but also the adjacent and refrigerated air will slowly descend. The drip-tray *D* is intended to catch the water collecting on *C*.

Although the resulting refrigeration is not sufficient to cool the entire chamber uniformly (for this a much greater quantity of liquid air would have to evaporate), yet within the area of the descending cool air current the physiological action is very noticeable. Such an appliance charged with half a gallon of liquid air will act during two or three hours, and might, for instance, be suspended from a lamp or from the ceiling in some other manner.

For mounting on a solid support,—a dining table, for instance,—the shape shown in Fig. 2 will be suitable. The products of evaporation rise from the vessel *A* through the pipe *r* and escape with a comparatively considerable velocity through the nozzle *a*, thus producing an aspirating effect upon the air

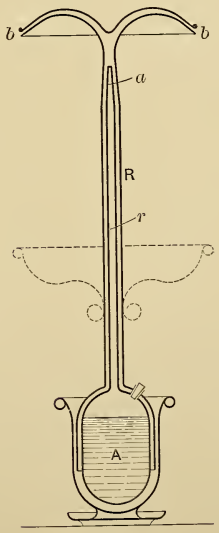


FIG. 2

contained in the tube *R* and inducing a current of the surrounding air to enter it from below. In this manner heat is conveyed from the external air both to the air evaporating in *A* and to the

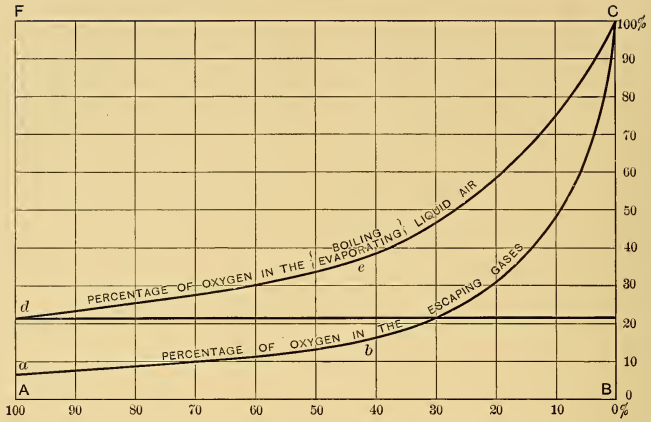


FIG. 3

vapourised air ascending in *r*, both ultimately escaping by the openings *b b* and distributing refrigeration to the surroundings.

Similar smaller applications might be noticed. But it is evident that we cannot to-day speak of liquid air as promising technical applications of great importance if there were no other properties of liquid air to consider beyond its low temperature. In this direction special weight must be attached to the circumstance that the two most important constituents of atmospheric air,—nitrogen and oxygen,—do not, during the evaporation of liquid air, remain in constant ratio to each other, but that the products of evaporation invariably contain more nitrogen and less oxygen than the evaporating liquid itself, and hence the latter will become the richer in oxygen the longer the evaporation continues. When, therefore, the products of evaporation corresponding to different periods are collected separately, gas mixtures of different constitution will result, and this has been actually made use of for obtaining chiefly gases rich in oxygen.

Fig. 3 represents the varying course of the volumetric constitution of the products of evaporation (curve *a b C*), and of the liquid residue (curve *d e C*). The quantity of liquid reveals at first the constitution of the atmosphere ($Ad = 20.8$ per cent. oxygen), whilst the first products of evaporation contain about 7 per cent. oxygen. The liquid is composed of equal parts of oxygen and nitrogen, when one-fourth of it is still extant. Only at the last instant of evaporation does the liquid consist of pure oxygen. Hence, we recognise that fractional distillation of liquid air alone is not suitable for the production of gas mixtures greatly enriched in oxygen. We shall see how this is, nevertheless, possible by the addition of another appliance.

In the first instance, we have to examine whether the production of oxygen from liquid air presents any prospects of so economical an action that we can recognise in it an advantage as compared with the industrial processes employed at present. This would certainly not be so if we were obliged to procure, by the aid of liquefying machines, the entire quantity of liquid air necessary for concentration down to a certain percentage of oxygen. The possibility of obtaining oxygen from liquid air has received technical importance only by the consideration that the cold developed by the evaporation of liquid air may be imparted to another quantity of air of a higher pressure, which thereby is reduced to condensation. If we pro-

vide for the transfer of the cold from the escaping products of evaporation to the incoming compressed air, so that the latter will enter the evaporator at its liquefaction temperature, then there will theoretically result for every gallon of air evaporating one gallon of condensed air, and the disbursement of energy for the entire plant will be now limited, first, to compressing the atmospheric air previous to its condensation, and, second, to compensating the losses of cold. The latter may either be combined with the former, by raising the entire quantity of air to such a pressure (20 to 30 atm.) that the requisite quantity of cold is produced by expanding it through a throttling valve, or the air to be liquefied may be compressed only to such an extent as its condensation will require, *i. e.*, to 2 or 3 atm., and the losses of cold may be compensated by adding an equivalent of liquid air provided by an ordinary air-liquefaction machine.

In the first description of the process in 1895 and 1896 the first of the forms referred to is explained, but since 1897 the latter construction has been employed in all practical trials. I may here remark that for a year a special experimental station has been at work in the neighbourhood of Munich. Since the requirement of energy is determined by the quantities of cold lost, and since such losses prove in proportion far greater with small experimental apparatus than with larger ones, it was possible to answer the question put by our industries as to the relation between production and consumption for large quantities of oxygen, experimentally only by conducting trials on a large scale.

Before describing the apparatus finally employed in this station I should like to describe the process again by means of the simple contrivance shown in Fig. 4 by way of better explanation.

The liquid air to be fractionally distilled is contained in the vessel *A*. During the first period of evaporation the gases, mainly composed of nitrogen, leave the counter-current apparatus *g* by the stop-valve *n*. When the enrichment of the liquid with oxygen has reached the necessary degree, *n* is closed and *o* opened for the discharge of the gases rich in oxygen. Atmospheric air is introduced into the vessel *B* in counter-current to the gases escaping under such a pressure (2 to 3 atm.) that it will condense on the walls of the vessel *A* forming the heating surface. After completion of the evaporation in *A* the condensed products are allowed to pass over from *B* to *A* by the valve *c*, and the evaporation may recommence after adding from the liquefying machine by the feed-pipe *e* as much liquid air as will be required to make good the losses. This apparatus possesses the disadvantage of an intermittent action, and is evidently not suitable for work on a large scale.

In whatever manner the apparatus serving to produce oxygen by fractional

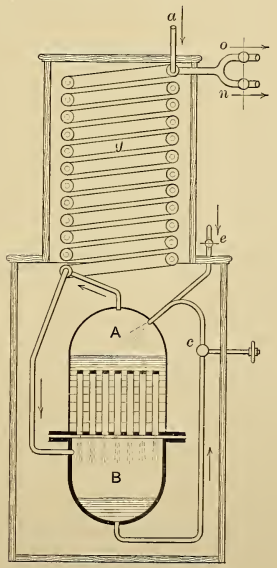


FIG. 4

distillation is, and will be, constructed, it must always comprise as its two essential parts, —

First, the counter-stream apparatus for

the exchange of specific heat between the incoming compressed air and the discharged products of evaporation, and

Second, the evaporating apparatus in which the latent heat of the compressed air will, during its condensation, be conveyed to the liquid air under evaporation.

More recently a third important addition has been made. When considering the diagram, Fig. 3, we have recognised the production of gas mixtures very rich in oxygen by fractional distillation as being unattainable, for this reason,—that approximately pure oxygen results only at the termination of evaporation, that is, only for a quite small residue of the evaporating liquid. By the adoption of a device well known in the practice of distillation (especially for alcohol), *i. e.*, the principle of rectification, this disadvantage can be met. If, in a rectifying column,—which may consist merely of a cylindrical vessel filled with glass beads or similar particles,—we allow the products resulting from the evaporation of liquid air very rich in oxygen to rise in a direction opposite to that of the condensed air entering from above, this latter will remove oxygen from the ascending gas current, and in its turn give off gaseous nitrogen, so that the condensed products will reach the bottom of the evaporator enriched by oxygen, whilst the gas current at the top end will contain only the quantity of oxygen corresponding to the constitution of atmospheric liquid air, *i. e.*, 7 per cent. This rectifying action,—as also the entire phenomenon of fractional distillation,—is explained by the circumstance that the boiling-point of oxygen lies about 23 deg. F. higher than that of nitrogen.

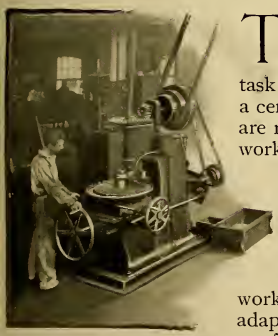
The enrichment of the evaporating liquid air by oxygen has been employed also for producing explosives by soaking combustible substances (*e. g.*, paraffine oil and cork charcoal), filled into cartridges in the form of powder, in liquid air, and thus impregnating them with oxygen in a fashion making them explosive under the action of detonators. And, indeed, explosives of the highest power have resulted, but their extensive use in practice has been hitherto limited by the fact that during the time elapsing between their removal from the liquid air and their detonation there will evaporate from the cartridges a certain quantity of the liquid air, depending as to relative amount upon the shape of the cartridge and the length of the period named. Consequently, the matter is resolved into one dealing, not with a stable body, but with a very variable substance, and this reduces the certainty of the explosive action. We may, notwithstanding, assume that the unremitting efforts to produce cartridges suitable for certain conditions will be followed by favourable results.

Lastly, we must notice the expectations dealing with the adaptation of liquid air for motor purposes. The position here is similar to that of employing liquid air for refrigerating purposes. If we cause liquid air to evaporate in a closed vessel we obtain a manifold volume of gases under high tension, which may, either directly or after combustion, be employed to drive engines. But this possibility has been invested with much too great an importance. When we consider that the mechanical work capable of being recovered from liquid air represents only a small fraction of the work indispensable to liquefy the air, then we shall be convinced that we can never speak of developing, by liquid air, motive power of an economical kind. But, as in refrigeration, cases may arise also here in which the question of economy will be of secondary consideration, whilst certain properties of liquid air may offer conclusive advantages. I refer, for instance, to submarine vessels and to conditions where it is of vital importance to reduce the weight of the motor to the utmost extent possible. In this connection I may mention the more or less successful experiments which have been made for automobile cars. And, indeed, efforts in this direction do not appear to be without possibility of success.

ART IN SHOP ARCHITECTURE. THE WORKS OF MESSRS. W. H. ALLEN, SON & CO., LTD., BEDFORD, ENGLAND

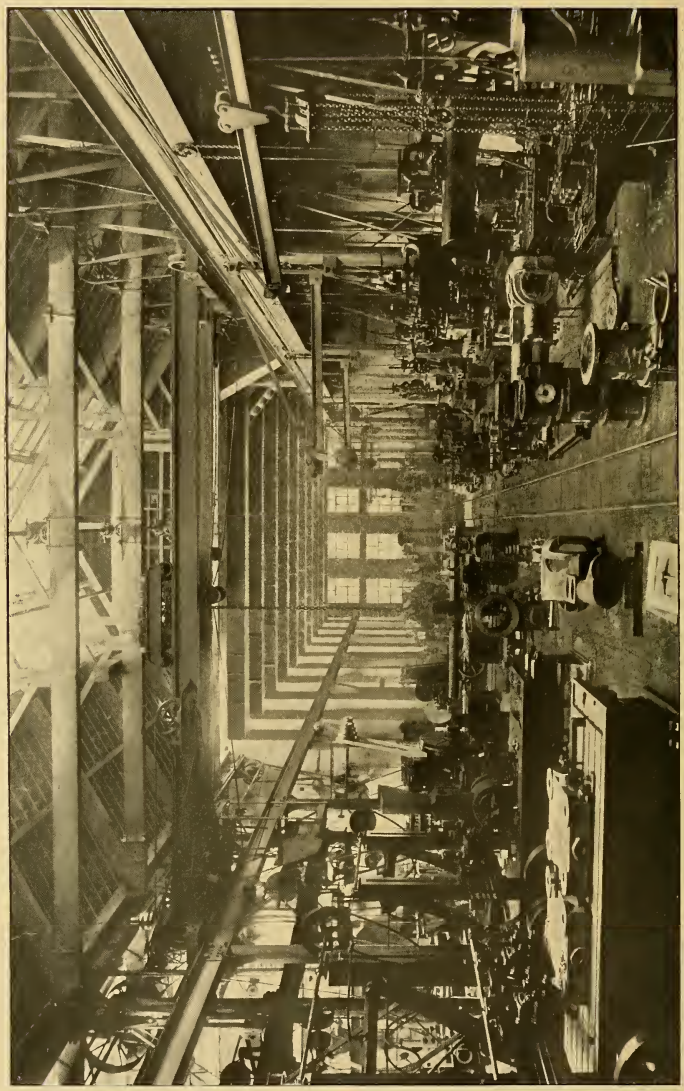
THE EQUIPMENT OF MACHINE SHOPS

By Joseph Horner

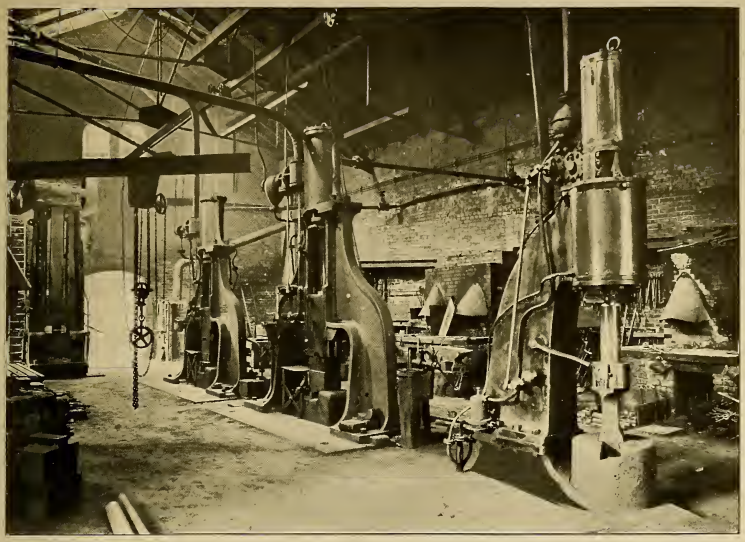


TO equip an engineers' works is as anxious a task as to build it. To a certain extent the two are related, that is, the works and its machinery must be adapted to each other. Still this does not absolutely hold good, because existing works are often ill adapted and poorly laid out for the modern machinery and plant with which it is sought to equip them. Alterations and extensions are thus often made necessary. It is proposed here to consider the broad questions that have to be settled in the purchase of machinery and plant. In order to be concise, it will be well to take the two problems involved separately. Machinery is the subject which is of paramount importance and interest in any works. The term includes machinery proper, much of which is also plant and much machine tools.

It is a more difficult task now than formerly to determine the best selection of machine tools for factories the products of which are not highly specialised. This seems paradoxical in face of the fact that these tools are now manufactured in immensely greater varieties than they formerly were. But there are two things which make selection difficult. One is that improvements follow one another so quickly that few tools have any certain tenure of undisputed possession. The other is that there are some tools the possession of which would be very desirable, but the purchase of which may not be justifiable. To give one example only of each, there is the great revolution in lathe design which has been going on rapidly during the last two years or so in consequence of the recent introduction of high-speed tool steels; and the demand for planed bevel gears, small quantities only of which are required in some shops, illustrates the second. When a firm sets out to equip a



A VIEW IN THE MACHINE SHOP OF MESSRS. FRANK PEARN & CO., LTD., MANCHESTER, ENGLAND



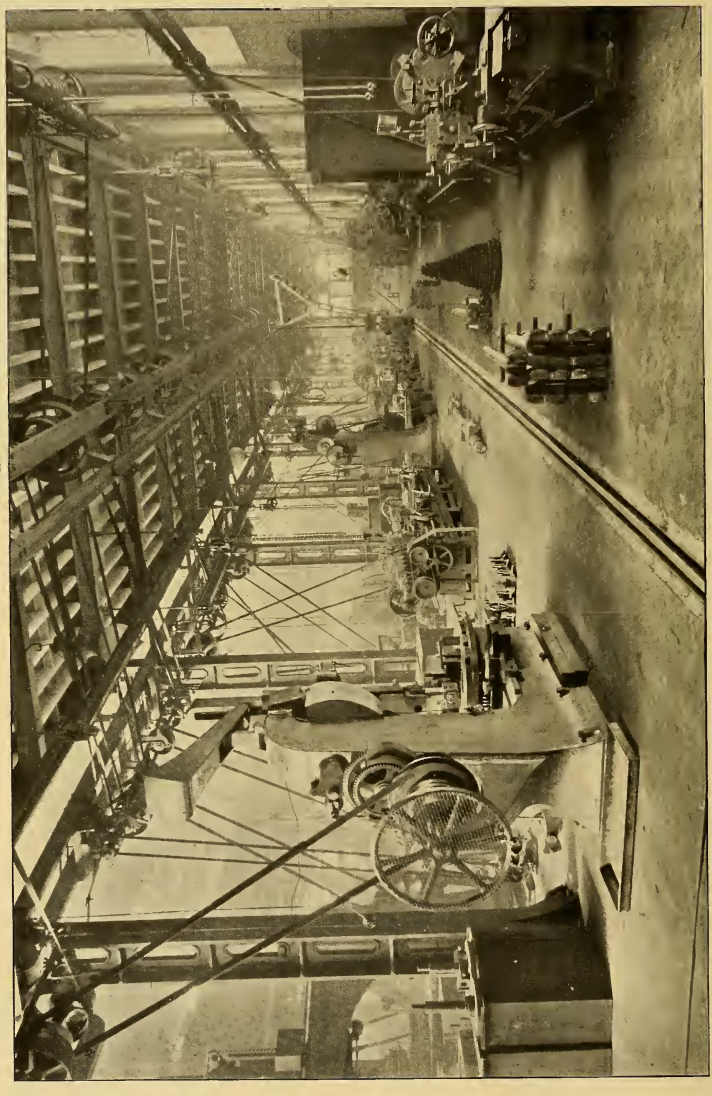
THE SMITHY AT THE WORKS OF J. E. REINECKER, CHEMNITZ-GABLENZ, GERMANY

shop with machine tools, whether *ab initio*, or with the object of extension, or of remodelling, the subject may thus become very complicated. Often a firm longs to be able to increase the volume of its specialised work in order to be in a better position to purchase money-making machinery. The problem is complicated by the fact that an engineers' works is an assemblage of shops in which about half a dozen separate and distinct big trades are carried on. Each has to be equipped with totally different sets of tools and appliances and run under separate management, each one of which demands technical knowledge and skill of a character distinct from that of all the rest. But these separate units are nevertheless interdependent, and some are very closely related, though the practice of the crafts themselves may be as opposite as is possible. An example of this occurs in pattern-making and moulding.

In the work of equipment and organisation, therefore, an engineers' works has to be regarded much as a physician regards the human body in which health depends on the regular fulfilment of the functions of many very diverse, but interdependent organs. The equipment of each one of these departments must thus be effected first as a separate manufacturing shop, and secondly as a department only, in close relation to all the others, and again particularly so in relation to one or two of the rest. The first-named problem may, in some cases, offer less difficulty than the second. A growing appreciation of the importance of the relations of the shops is one of the most marked characteristics in modern works design by comparison with the older ones.

It is not practicable in the compass of a single article to treat each of the half dozen or more different departments of an engineers' factory in detail. The remarks to follow will, therefore, relate to the questions that apply in greater or less degree to each one of the shops.

Taking the question of machines first, the following points must be considered in all departments alike. The selection



UNDER A SIDE GALLERY IN THE LARGE SHOP OF MESSRS. BELLIS & MORCOM, LTD., BIRMINGHAM. THE MONO-RAIL ELECTRIC CRANE SHOWN IN THE BACKGROUND HANDLES THE HEAVY WORK FOR THE TOOLS IN THIS SECTION

of types comes first. Broadly, this is not a difficult task to a clear-headed manager. But big blunders can be made here by a man of narrow views, and especially one whose knowledge is not abreast of what is being done in other shops. The time has gone by when the equipment of lathes, planers, shapers, slotters, drilling machines and the rest in standard and common types sufficed for competitive production. Thus, circular work is no longer appropriated exclusively by the lathe, nor is the production of plane surfaces by planer and shaper, nor key-grooving by the slotter. Many readjustments in tasks of these and kindred kinds have been going on in recent years, with increased production and also often precision of results.

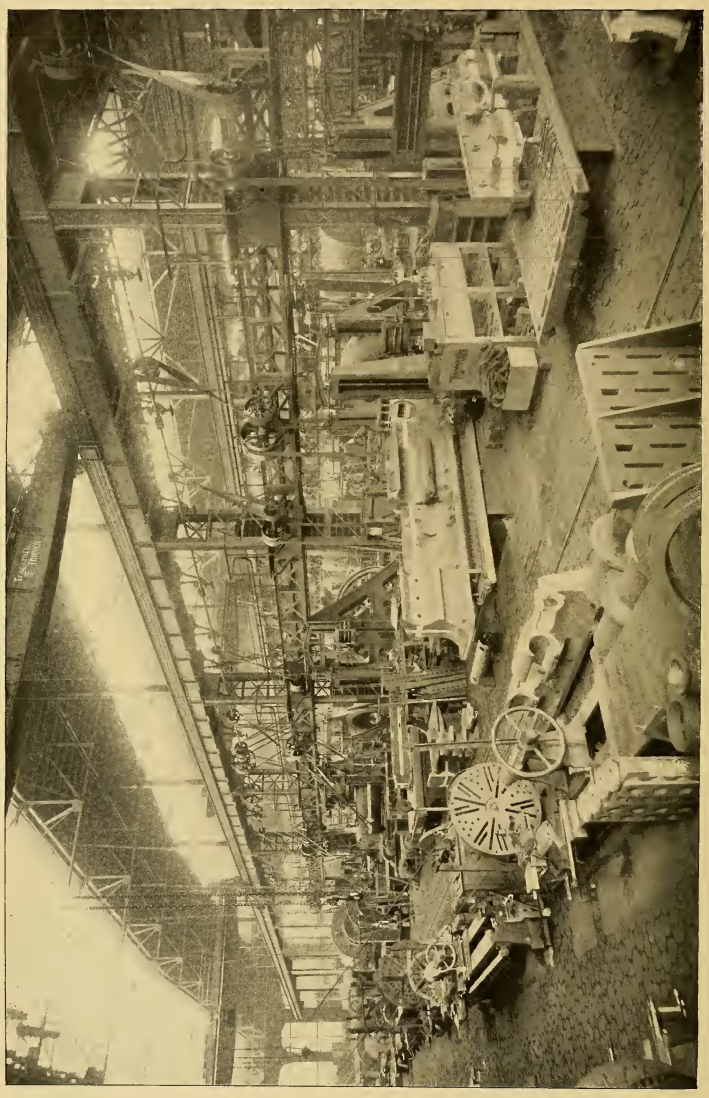
To keep abreast of these changes in practice is no easy task, and it is complicated by the fact that the question is not merely one of the utility of a given machine in the abstract, but of its special adaptation, or otherwise, to the requirements of the firm where its installation is contemplated. For example, a special kind of machine, such as a planer type of gear cutter or a link grinding machine, though ensuring more exact and accurate results than those which are obtained by circular cutters or by hand lapping, in the respective cases, cannot be considered as an essential part of the equipment of all shops.

Another point which is akin to this is that of the maximum capacities desirable of machine tools. It is annoying, after machines have been purchased and fixed, to find that the accommodation provided for producing work of growing dimensions soon becomes insufficient. The alternative then is to rig up temporary devices, or to sublet such sections of the work out to other firms. The cost of machines bounds up with increments in capacity, and soon appears to be prohibitive; but the outlay may be necessary and even true economy if large work is to be done properly. Such machines are not necessarily unremunerative, because pieces of small and medium dimensions can be put on them, as well as of large sizes. Strictly taken, this is not good practice, because the bigger machines are rated at a higher charge per day than the smaller ones, and it will often happen thus that small work put on a big machine becomes heavily surcharged. But this is to be preferred to allowing the machine to lie idle for any considerable periods of time.

Another difficult problem arises in the case of new and untried machines. Purchasers fight shy of these until their capabilities or promises have been put to test by rival firms. A good deal has to be taken on trust here; hence the reason why some firms will put down tools on trial and remove them if found unsatisfactory. Some machines are like horses; they have incurable vices that cannot always be understood or explained, but which are managed better in some hands than in others. In some shops they give no trouble and become valued servants; in others they are not considered successful. The prejudices, habits, and methods of men or managers account, to some extent, for these differences; but they have to be reckoned with.

It is good policy on the part of machine tool makers to send one of their own men to take charge of a new machine for a week, putting it through its paces and showing its capabilities. It is a fact that for lack of this in many instances machines have never been worked to their fullest capacities; they have begun badly, and the pace thus set has remained at that permanently.

A burning question to-day which greatly affects the selection of machines is that of the relative proportions in which skilled and unskilled labour can be employed. It affects all departments in a greater or less degree, the pattern shop excepted. The prospect of being able to dispense largely with skilled labour by the laying down of machines to be operated by lads is a seductive one. But one's fingers may easily get burnt in this attempt. Automatics that do not require skilled attendance are adapted only to those shops where there is a sufficient volume of special work to keep them constantly employed. With these, numbers of semi-automatics must

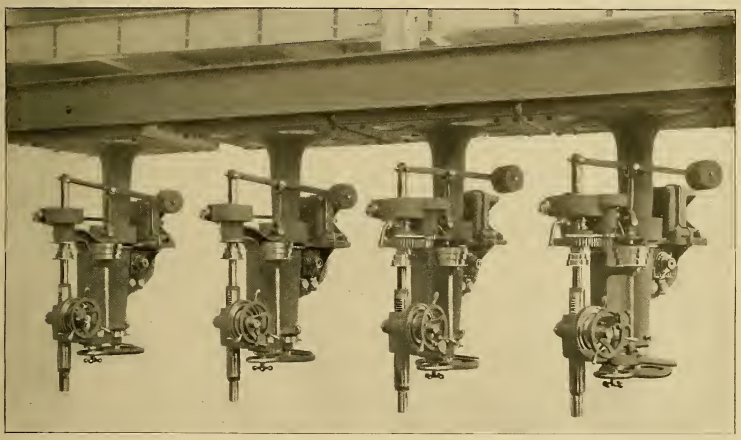


A VIEW IN THE SHOP OF MESSRS. ESCHER, WYSS & CO., ZÜRICH, SWITZERLAND

be included, in which the skilled man is required for fixing up, while the unskilled man takes charge of the operation of the handles and levers. The tendency is slowly setting towards the lessening of the numbers of skilled hands; but this also should come as a development, and never as a revolution.

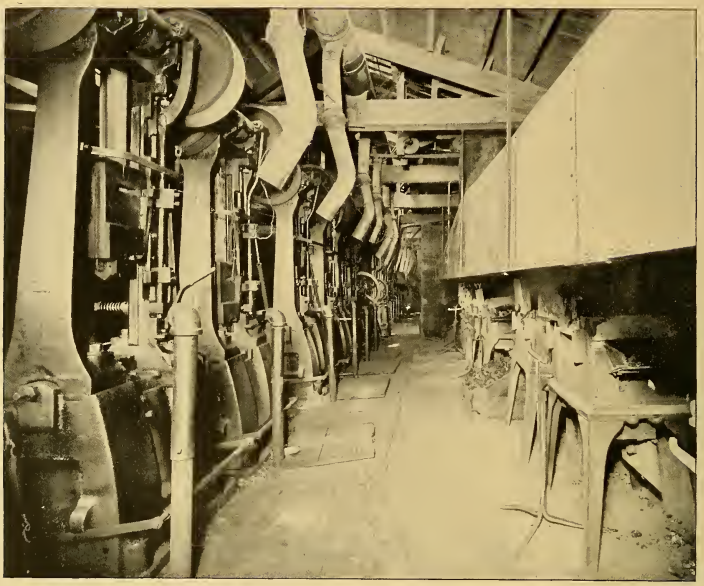
These several problems assume their greatest magnitude in the machine shop and turnery. But they have become burning questions also in the foundry, the smithy, and the boiler and plating shops. The foundry is being invaded by machinery and machine tools to an extent that is utterly subversive of the ideas that prevailed only ten years ago, without going back any further. No manager, even in a shop dealing with a miscellaneous and general class of castings, can afford to neglect the material economies which are offered by moulding machines, by a compressed air supply, and by special machines for fettling.

In the smithy, as in the foundry, a very moderate volume of repetitive work justifies its transference from the skilled to an unskilled section of the hands. Die forging is as elastic a system as machine moulding, being economically suitable alike for a dozen similar pieces, or for a thousand. But an intimate knowledge of the details of such a system must precede its installation. Here a firm might easily lose a lot of money by getting mixed up between the two systems, laying down plant and making stamps suitable for large quantities of forgings when the numbers required are few; or, on the other hand, adopting makeshift devices for the production of hundreds of similar pieces. The fact is, die forging, as a system, dispenses with trained smiths; but die forging as an adjunct to the work of the anvil does not. The latter is an economical aid, only supplementing and completing the anvil work; the former affords enormous economies, but requires special plant and a sufficiently large volume of similar and repetitive work.



FOUR SUSPENDED ELECTRICALLY DRIVEN RADIAL DRILLING MACHINES FOR BRIDGE WORK. THEY ARE FASTENED TO A PRACTICABLE SCAFFOLDING AND CONVEYED OVER THE PARTS TO BE OPERATED UPON. MADE BY MESSRS. COLLET & ENGELHARD, OFFENBACH ON THE MAIN, GERMANY

The enormous weight and dimensions and number of the machines which are required for heavy plating and big boiler work is one reason why many shops are very insufficiently equipped with these, and why the heaviest work in these departments lies in the hands of compara-



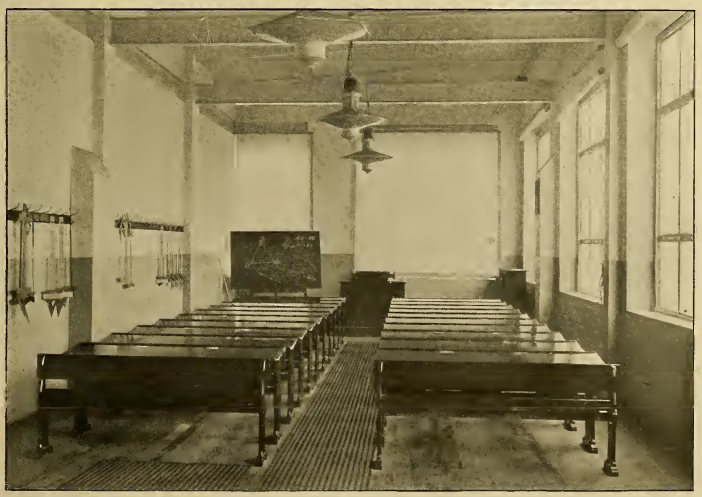
A VIEW IN THE DROP FORGING SHOP OF MESSRS. J. H. WILLIAMS & CO., BROOKLYN, NEW YORK. THERE IS A LARGE HOOD OVER THE ROW OF FURNACES TO REMOVE GASES AND HOT AIR, AND ABOVE AND IN FRONT OF THE HAMMERS THERE IS A DUCT OF A COOLING SYSTEM WITH A FRESH AIR NOZZLE PROJECTING DOWNWARD OVER EACH MAN' HEAD

tively few firms. Many shops are compelled for this reason to put their heavy flanging out, or to sublet entire jobs, which again swells the volume of orders of the heavy shops.

The difficulty with which most firms are now confronted is to decide to what extent they can afford to substitute, or are justified in substituting, new tools for old ones. A firm knows, or should know, its own requirements better than an outsider can, and when money is being made by existing tools and methods there is a strong case against making a change. Many examples of this kind will occur to the minds of every shop manager. On the other hand, the conservative habit of mind is much too strong in some establishments, and, unless checked, it generally ends in a scheme of amalgamation or liquidation. These problems are very difficult of solution; but they can mostly be resolved into matters of capital outlay and interest, assuming, of course, that there is a full knowledge of the output and quality of the work done on rival machines and by rival methods.

These problems touch every kind of machine tool, some more than others, and the rivalry rages with an intensity that has no parallel in the easy-going days of our fathers. Clearly, the first step is to become acquainted with the capabilities of rival tools, not in the abstract, but as applied to a firm's own class of work. This helps to explain why some firms do not seem able always to obtain a certain kind of tool which is exactly suited to their requirements, and prefer to build just what they want. There are many shops in which something special is to be seen,—made, not for sale, but simply for the firm's own use; and appliances other than tools occur in much larger numbers.

The selection of tools, even when made with the greatest care, backed up by sound judgment and wide experience, is only one-half the business involved, for the most suitable arrangement of the same out of several alternative methods has to be duly weighed and determined. It is better understood now than of yore that a bad arrangement of tools means loss, just as a bad selection of tools means loss. It affects results in two ways, first, in the classification and centralisation of work and groupings of men and boys; and second, in the carriage of materials and of work. It is hardly possible to lay too great stress on these matters, and their importance grows with increase in dimensions of work. and other machines. But in all works the broad division into heavy and light machines can be observed without attempting a very close arrangement of the machines. Thus it is a matter of less importance that all lathes, all planers, all drilling machines shall be grouped together than that all heavy machines shall be grouped apart from all light ones. It is very often advantageous to have the heavy tools, though of different classes, in close proximity, so that work can be transferred from one to the other with a minimum of handling. Obvious though this seems, it has not been always, or even generally, observed in the older shops, and much loss of time has resulted. By observing

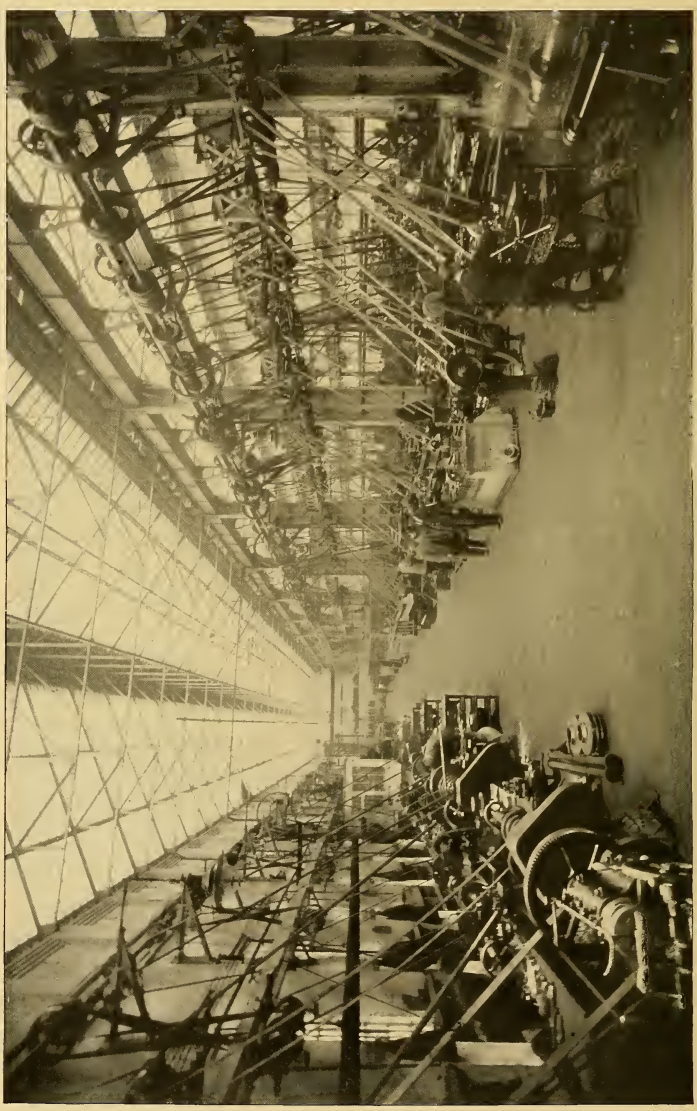


AN APPRENTICES' SCHOOL ROOM AT THE WORKS OF MESSRS. LUDWIG LOEWE & CO., BERLIN, GERMANY. ALL APPRENTICES ARE GIVEN FREE INSTRUCTION IN DRAWING, MATHEMATICS, MACHINE DESIGN AND OTHER ALLIED BRANCHES. ATTENDANCE IS NOT COMPULSORY, BUT USE IS MADE OF THE SCHOOL BY ALL THE APPRENTICES

In a very small shop they may be altogether neglected, but never in the larger establishments.

Only in some special industries is it possible to equip separate shops with machines identical in character, as gear cutters, automatics, drilling, or milling, this broad classification into light and heavy, the shafting, the hoisting, and the hauling appliances can be adapted to heavy and to light duties absolutely, instead of being adapted imperfectly.

Outside of these groupings there is the growth of portable tools to be



THE LIGHT MACHINE SHOP AT THE WORKS OF MESSRS. YARROW & CO., LTD., POPLAR, LONDON

counted on, a growth of which the value lies chiefly in shops where heavy work is the leading line of manufacture. If these do not exactly threaten the survival of the heavy machines they certainly lessen the need for the frequent handling and transference of work from one machine to another, and, therefore,

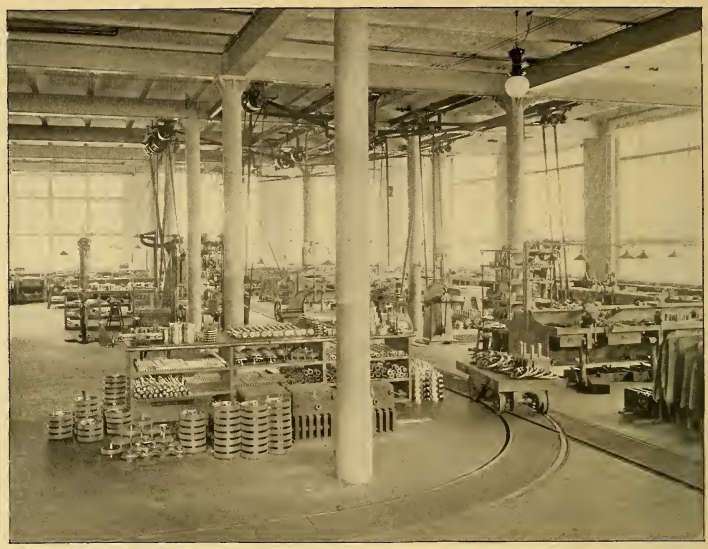
The equipment of plant of a works includes the power plant, the machinery for hoisting, the agencies for transportation and communication between departments, the appliances necessary as aids to the work of the shops, the lighting, heating, ventilating, and so forth. The question of the quantity of power

WASH ROOM AT THE WORKS OF MESSRS. J. H. WILLIAMS & CO., BROOKLYN, NEW YORK. THE SINK HAS OVERHEAD SPRAYS. THERE IS ALSO A BATH COMPARTMENT WITH LOCKERS, SEEN IN THE BACKGROUND

they prove a great source of economy when used with intelligence.

In drilling, reamering, tapping, keyseating and planing done on massive castings and forgings, and on work in course of erection, the portable tools have proved most valuable time-savers. In the boiler and plating shops the portable drills, riveters and calking hammers are equally economical. Of the superior utility of these tools and methods to the older ones there can be no question in any shop doing heavy work, as there may be in the case of some other innovations.

required in a works is not so difficult a one to settle as it was formerly. A considerable amount of data has been gathered respecting the power absorbed by different machines working under conditions of light and heavy duty that was not available to the earlier engineers; and the exact power which an engine or dynamo will develop is also readily obtained and guaranteed. Shafting losses can also be easily ascertained. It is, therefore, a very simple thing to square calculations on paper on the basis of power generated and power absorbed. But an ample surplus must be allowed,



LIGHT FITTING DEPARTMENT IN THE WORKS OF MESSRS. LUDWIG LOEWE & CO., BERLIN. THIS VIEW GIVES A GOOD IDEA OF THE GENERAL ARRANGEMENT,—THE RAILWAY SYSTEM, BENCHES, RACKS FOR WORK, ETC.

and room for future extension must be provided in any calculations of this kind. The important point is to allow ample room for growth. Make the power house big enough, and lay down fresh units as required. The high-speed, high-powered vertical engines now used, of various types, occupy much less room than the old engines of equal power did, and can be added in sets from time to time as required by the growth of a works. The power house of a works never occupies a very large area, so that it is easy to leave room in the original design for future additions of generating plant.

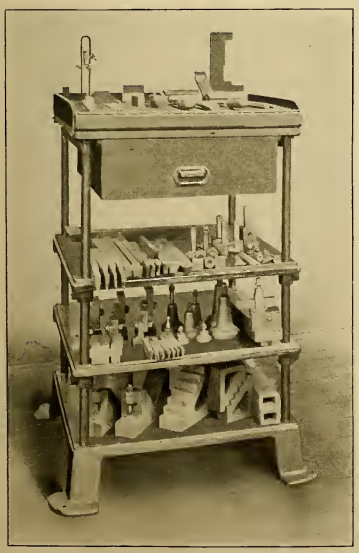
The questions of the equipments for driving and for hoisting does not stand as it did a few years ago; electricity and compressed air between them have radically changed both. To a certain extent these agencies are rivals, but only within a comparatively limited area. The latter agency scarcely touches the driving of machine tools outside of the portable types, nor is it used much for hoisting tackle, excepting in the lighter class of travelling crabs and hoists. It is not a serious rival to electricity in the heavier cranes, whether they are of fixed or of travelling types. Neither is it adaptable, like electricity, to transmission over long distances. The air compressing plant must not be located far away from the tools and machines to be operated, but the power house generating electricity can serve the largest works equally efficiently with the smallest. The elasticity of the electric system, therefore, as well as its potential economies, explains and justifies its phenomenal growth.

An equipment of light railways is now considered almost indispensable in any factory scheme. The old shops have been sadly wanting in this most valuable kind of plant. And yet there has never been any difficulty in laying it down. Even where it has long been in use, its full utilities have not usually been

secured, because an essential has been neglected,—that of free communication between the shops themselves and between the shops and the yard. Attention to this would often save at least one transference of material and of finished work, but labourers' time did not count for much in the older shops.

The yard track is generally of a 4-foot 8½-inch gauge, and that of the shops a narrow one, say of 18 or 24 inches. Some work is, of course, too massive to be carried on the narrow-gauge trolleys. But this is managed by carrying the broad-gauge track just inside the doors of the shops, so that the trolleys can be run under the shop travelling crane for handling the work, either off or onto the trolley. The narrow-gauge tracks can also be continued out into the yard, between the broad lines, and so be used when occasion arises to avoid one transfer.

A matter of increasing importance in the equipment of a factory is the provision of stands, racks, cupboards and other conveniences for the temporary storage of tools and appliances. These were unconsidered trifles in the old shops, being practically non-existent in most of them; but almost as if by magic their value is now becoming appreciated. A place for everything and everything in its place is at present observed most stringently in the best shops. This applies to all the departments alike, from pattern shop and foundry to smithy and the machine and fitting shop. It is a part of the wider question of storage of materials, from pig and scrap by hundreds or thousands of tons, to screws, nuts, and rivets, and other small stores.

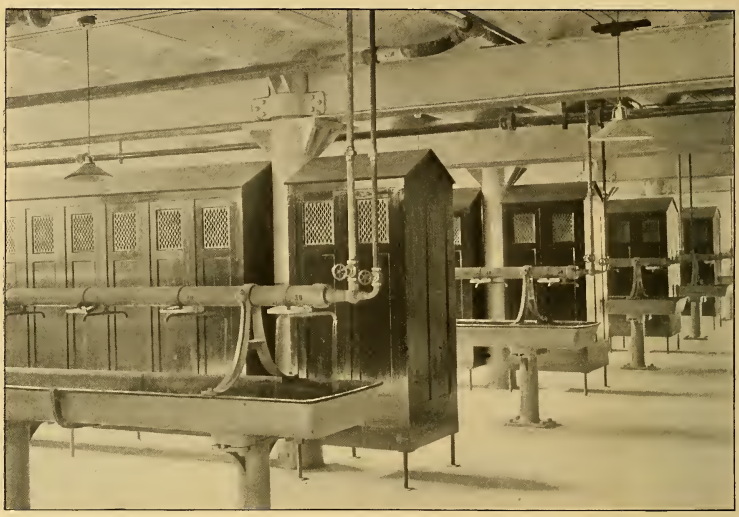


A GOOD SHOP STAND DESIGN

A CONVENIENT FORM OF BOLT RACK

Many cases are known of work being absolutely lost in shops due to lack of good arrangements. Work has been entered in the books, the entries of castings and even machining have been looked up, search has been instituted for the missing articles, but in vain; and orders for the missing parts have had to be repeated. It seems hardly creditable, yet it is true. In a shop where order is lacking, things that are not required immediately soon become covered up or shifted by mistake and mixed up with parts to which they do not belong.

Another cause of confusion exists in the practice of not scrapping bad work immediately, but of putting it aside in the belief that it can be "brought in" some day. It seems a pity to send a



WASH AND WARDROBE ROOM FOR WORKMEN AT MESSRS. LUDWIG LOEWE & CO.'S WORKS. THERE ARE HALF A DOZEN DEPARTMENTS LIKE THIS IN THE DIFFERENT BUILDINGS. IN CONNECTION WITH THE SMITH'S SHOP AND FOUNDRY, TWO SHOWER BATHS ALSO ARE PROVIDED. THESE ARE USED AND APPRECIATED BY ALL THE MEN

sound piece of work on which money has been spent, to the scrap heap simply because a hole is bored or drilled slightly full to size, or because a trifle too much has been taken off a face. Some day on some other job new parts may be accommodated to fit these. And so they are allowed to accumulate until they become nuisances and snares.

The observance of order in a shop is impossible unless places are provided for everything, sections of work in progress and tools,—even to the most insignificant of articles. Look at the beds of lathes. They are crowded with mandrels and tools piled up on the bed itself or in a box; or they are thrown into boxes underneath, or even loosely on the floor, and often jumbled up along with pieces of work.

Planing, shaping, and slotting machines do not offer convenient areas for such stores, and so the floor in the vicinity of these is often strewn with debris, around and among which men have to pick their way cautiously. All this can be avoided by the use of cabinet cupboards, of spanner and bolt racks, and by a good supply of stands distributed about the shops close to the machines. The originals of these stands are old in smithies, where they are indispensable for carrying odds and ends of rods and bars and stamps.

Since the introduction of machine shop and other stands in large numbers it has been recognised that wood is not very suitable for their construction, chiefly on account of its bad appearance after being in use for a short time, due to unavoidable oil and dirt. For this reason a number of different designs are made in metal,—cast iron and steel plate predominating. The chief disadvantage of cast iron is its liability of breakage by work or tools falling on the corners and edges.

The manufacture of shop stands in specialised form is an indication of their growing importance, since those which any firm can make for itself, have hitherto sufficed. It is a common sight now in the

best shops to see a stand ranged alongside each machine tool to carry the small appliances which are necessary, and which would otherwise lie on the machine bed or on the floor. This makes a considerable difference in the neat appearance of the shop, and in the saving of damage.

The equipment of a works includes quantities of plant for the various shops that cannot be classed as machinery. It is difficult to fix on the amounts of these required beforehand. Take the foundry, for example. A well-equipped foundry of fair size contains many hundreds of box parts of all sizes and shapes, dozens of wheelbarrows, shovels, rammers, ladles, skimmers, and much beside. The only way to equip is to proceed cautiously. The work to be done must be carefully calculated and classified, and a sufficient amount of plant must be laid down for a working outfit. It is better to do this, adding continually to the stock, than to make a large quantity, some of which may, after all, be only partially employed.

The plant,—shop tools being the usual term employed,—is always being increased year by year in every shop. Some is of a permanent, much of a temporary, character, required for special jobs, and the question of storage of all this is often a troublesome one. Much of it should go under cover, but the exigencies of shop space often render the yard the only place available. Foundry boxes are often piled there, though only the heaviest should be left out in the open. Pig-iron is frequently left exposed to the weather, so is scrap iron, and rain and rust cause waste and unnecessary dirt. Sand must always be in covered sheds. The templets used in boiler shop, plating shed, and smithy ought to be kept under cover. The bending and flanging blocks are almost of necessity stored out in the open yard adjacent to these shops.

A secondary advantage follows from the observance of the systems here insisted on, and that is the conservation of floor area. This is of so much value that it should never be littered up with

THE WORKINGMEN'S DINING HALL AT THE WORKS OF J. E. REINECKER, CHEMNITZ-GABLENZ, GERMANY

stuff that can be stored above the floors or outside the shops. In the old shops floors were, and are, frequently of earth and broken stone, seldom of good, sound timber construction, as in some of the newly constructed shops. Floors are too often regarded as dumping places for all kinds of stuff, as well as for their legitimate function of machine and bench supports and erecting areas. Trestles, castings and forgings are allowed to lie about, mingled with pieces of odd timber, bars, spanners, slings, etc. Dirty floors and dark shops invite and condone such, but clean boards and full light of day show up and forbid such abuse.

Lighting by gas is now not considered in a few works. Arc lamps, high up near the ceiling or along the galleries under the cranes, give a diffused light throughout the shops, and incandescent lamps are scattered about, round and over the machines, several being used with machines of large size. Candles, lamps, and dips need no longer be used, as an incandescent lamp on the end of its flexible wire enables the workman to probe into the dark corners or inside of work. The lamp may then be hitched up somewhere inside the job and left there.

A shop is not complete, as ideas go now, unless its equipment includes adequate provision for the comfort and convenience of the workers. It is not right, for example, that the men should have to sit along the curb of the pavement outside the works to take their meals. A good firm should provide mess rooms with ample accommodation for all hands, and with proper facilities for making tea and coffee, and for some cooking, too. More than this, the men are not demoralised if a few newspapers and illustrated weeklies are scattered about, technical publications, of course, included. Nor do they work with less energy if decent lavatories permit washing off at least the outer crust of dirt and grease before leaving for meals. Neither do they fail to appreciate decent sanitary appliances.

In the equipment of shops the last worry comes in when selection of hands has to be made. The question of union or non-union labour, the proportions of skilled and unskilled, the rate of wages, whether above or below the average, the question of piece or the day-work system, the limitations of the duties of foremen and managers may be as difficult of solution as that of machine tool and plant equipments. But this opens out another set of problems entirely which cannot be treated here.

THE LABOUR-CAPITALIST

By Frank C. Perkins

An interesting possibility in the way of labour problem solutions is that suggested by Mr. Perkins in the following article, the gist of it being that the union labouring classes, through their representatives, should gradually acquire shares of stock in the industrial enterprises with which they are identified, so as to ultimately represent important interests, with a voice in the management of the businesses. Labour's capital, so invested, would serve immeasurably more efficiently in labour's interests than if paid into strike funds, and would, in the author's opinion, lead to industrial peace and harmony all around.—THE EDITOR.

THAT the working together in harmony of capital and labour for their mutual interests is the desired panacea for strikes and other labour difficulties is acknowledged by all. To attain this end some large manufacturing establishments have offered shares of stock to their employees at tempting prices, while others have arranged for bonuses of stock to be given to their workmen after certain periods of service.

In order that a union workman shall take a special interest in his work, he must see something in his single share of stock, over and above the small dividend it will pay him. If he recognises in it a means of obtaining fair treatment without the necessity of striking, he will still further appreciate its value. Thousands of shares of stock scattered among his fellows would be valueless for this purpose unless they could be voted in a block. Union men do not appreciate the power they have within their reach if they will but grasp it. A great labour parade is passing, with 100,000 men in line. It affords an excellent illustration of the numerical strength of the trade unions of the present day. Consider, too, what it means financially. Imagine a ten-dollar bill sticking out of the pocket of each man as he passes. "Small capital," you say. True, as an individual; but apply the labouring man's motto as it is drilled into him, "In union there is strength," and immediately you have a million dollars.

If the unions buy the stock for the men as individuals, and vote it as a unit, we see at once what a power it becomes. The men would then not find it necessary to strike to obtain consideration, an interview, or a possible increase in wages. They would also hesitate to strike and possibly ruin or depreciate the stock which they would then own in large amounts collectively.

Profit-sharing plans in the form of gifts of stock would be attractive to a marked degree if the owning of the stock would in any way benefit them other than by the small profits they might receive on the stock. Regardless of the donations of any stock which manufacturers sometimes make, trade unionists could soon own a large interest if they would form a financial plan for obtaining shares regularly through the stock market, by forming stockholders' associations in their unions. Even if a controlling interest is not obtained, they would be entitled to a representative on the board of directors, owning collectively perhaps as large a block of stock as any of the largest stockholders.

The Golden Rule is all well and good, but it cannot be depended upon among either the capitalists or the labourers. If the labouring man becomes a capitalist, then the Golden Rule will apply;

for everyone, rich and poor, employee or employer, is willing to treat himself well. It is only by making their interests common that both manufacturer and workman can work together to the best advantage.

Take, as an instance, the recent anthracite and bituminous coal strikes in the United States, with union miners numbering a quarter of a million men. Ten dollars do not make a capitalist, it is true; but a quarter of a million men paying twenty cents a week into a union stock fund mean ten dollars per year, or a total of two and a half million dollars for a single year. This is a goodly capital to be controlled by the men who furnish all of the labour for operating the mines as well. Is it not fair to presume that with this invested in the companies which employ them, the men would not have to strike to obtain a hearing?

The proper union officials might buy the stock on the exchanges, month by month, as the money came in, little by little, from the men. In time they could control a large amount of stock, so that they would be entitled to a representative upon the board of directors, and they could vote upon that stock for their interests through that man, who might be the president of the union association of stockholders. The men would then be able to know the condition of affairs in the corporation through the reports to the stockholders. If the earnings were such as to warrant an increase of wages they would get it, and if they did not get it in wages they would get it in dividends. At any rate, they would hardly vote for a strike to depreciate the value of their holdings.

If there were no dividends, and losses instead of profits, then the men would, for their own good, be more satisfied to accept a cut in wages; but, as stockholders, they could demand that all of the salaries be cut, from the president down through the entire list to the poorest paid man or boy. Now it is frequently different; the salaries of the officials usually remain the same, and the cutting is done only at the payroll of wages to the labouring man.

There is another feature to this labour union financial plan which is well worth mentioning. At present, large insurance funds are raised in many unions for sick benefits, death claims, and funeral expenses. Large accumulations are also made for use as defence funds in times of strikes. Now, if the cause of strikes were largely done away with, these funds would buy a vast amount of stock and bonds of the works with which the men are identified.

The interest from the stocks and bonds could be used for sick benefits, and, if a workman died, the union purchasing committee could buy his stock and pay the money to his widow or his heirs. This plan means to a workman a protection in time of sickness and accident, and it means an income for him in his old age when he can work no longer. If he be thrifty, industrious, and saving, it may be said, he will be well fixed, anyway. This may be so, but how many think of that as they go along from day to day? If each workman invest, through his union, in stocks and bonds which they purchase for him, he will surely have something in his old age. As he pays in sufficient money to cover the price of each share of stock, it is transferred to his name; when he becomes old and cannot work, the capital which the stock represents is paid to him in cash. If he should wish to build a home, it might be used as his collateral on which to borrow the required money.

From the standpoint of the officers of the union and the present business agent, walking delegate, and agitator, so-called, the plan may be opposed; but if looked at aright it means a still more secure position for him, with added duties. He then becomes the business agent of the union workman in a new and truer sense of the word.

From the standpoint of the employer and capitalist at the works, it means better work from the entire labour force of the shop, as each man watches his neighbour to see that he does not shirk. If all the men have an interest in the stock of the concern, it means a greater output, and the saving of that vast loss to the business man whenever

there is a strike. It means union of strength, of labour and capital. Their interests become one and the same, and all alike are benefited.

It may be asked whether it is a safe investment to buy stocks or bonds, from the employee's point of view. If the capitalist risks large sums in the venture, could there be a more natural or better place to put the labourer's savings than in the establishment in which he works and earns his daily wage? If that shop is successful, the workman's work is assured him, and, if unsuccessful, he suffers as a result. Therefore, from the side of the employer and the employed as well, is it not a wise plan to induce him to identify himself with the works and use his utmost strength, energy, and skill in making that business a success? Under the present conditions he is often seeking for a reason to strike, antagonising that corporation which gives him employment, and doing everything he can to cause a failure of the establishment.

In reply to the question which might be asked as to whether the capitalist would not ultimately antagonise such a scheme of union stockholding, one can admit that in some instances he might; the stock could, however, always be bought at a trifle over the market price. Most capitalists would consider their investment safe, not believing the workmen would ever gain a controlling interest in the stock.

Some would consider it safe even if the labouring element owned a controlling interest in the corporation. The capitalist now not only owns the common stock, but also the bonds and preferred stock. He would be assured the interest on his bonds and preferred stock before the common stock of the labouring man could draw any dividends whatever. The men would certainly not act in such a manner as to ruin their common stock. There is little question that the men, as stockholders, would work harder for the success of the manufacturing plant than before, and there would be less contention as to wages, as the profits would come back to them in dividends in any case.

Few men consider what the enormous weekly or monthly pay-rolls of a great concern amount to in a year. What proportion of the gross income of a great corporation is paid to the working man? Take a manufacturing plant of 10,000 men whose average wage is two dollars per day! In a year of 300 days six million dollars are paid to these labouring men. This is often more than the entire materials used amount to and more than all of the other running expenses put together.

Take the railways of the United States, with a million employees, whose wages in a year would amount to more than five hundred million dollars. This is more than all the other expenses of the roads, including coal, supplies, and repairs. Where does the largest proportion of the gross receipts of the large railways go? Always to the workingman. He does not realise his importance financially. Alone, his capital amounts to little; combined with that of all his fellows, it is a mighty power.

Consider the effect of a part ownership of the great railways by the million employees, from the engineers, firemen, brakemen, and conductors of the train crews to the switchmen, freight handlers, and labourers in the yards and along the tracks, and from the highest officials in the main offices of the companies to the poorest clerks and station agents in every town throughout the land. One can hardly imagine what a power they would represent to prevent labour troubles if such strikes were contrary to their interests. One million employees investing, through their local unions and brotherhoods, fifty cents per week, or twenty-six dollars per year, would represent an invested capital in the stocks and bonds of the railways of the country of twenty-six million dollars in a single year. Under these conditions how long would it be before labour troubles would be settled by other means than strikes?

The railway men, who are usually well paid and could easily pay into the union the amount mentioned, would be considered not only a great power as controlling the wonderful transportation

facilities of the country through their daily toil as labourers, but also as capitalists. They would own in a short time a majority of the stock and bonds; if not, at least such a large amount as to be carefully considered in every action of the railway corporations.

As great additional trusts are established and other immense combinations of capital are effected an enormous labour trust is bound to come into existence. Labour unions are sure to combine their capital in the end, and nothing can stand before them. Capital and labour will then be united in a bond so strong that it can never be broken, for their interests will lie along the same lines.

This is not socialism. There is no common socialists' fund, and the present existing conditions are not changed in the least. The men simply buy the stock through the unions and own it themselves, not the union. The officials could purchase it for them in such a way that they could pay for it on the installment plan. As fast as each has paid in the value of a full share, it is transferred to him. True, the union votes it for him, but only as large blocks of stock are often voted, by proxy.

The greatest opposition to a union stockholding plan would, without doubt, come from within the unions themselves. It would be difficult to bring into existence such a state of affairs in connection with many trades and many small establishments; but in the case of a large industry, of which there are many whose stock is quoted on the market, the unions working directly for those manufacturers might easily combine.

An association of stockholders of all the union men working in a single great plant of even 10,000 men would soon be in a position to be of great benefit to the workmen. It would cause them to lay up something for a rainy day, making the unions savings institutions, requiring only a small payment each week for such a purpose. There is no money paid into any institution more religiously and regularly than the dues which members of labour organisations pay, and assessments to maintain their standing as union men. They now have their great defence funds and sick benefit funds. What greater means of defence could they have than the proprietorship of a large amount of stock and bonds in the works in which they labour? At present the defence funds are dissipated by every strike.

Strikes are like two-edged swords; when used in the war between capital and labour they cut both friend and foe alike. While more than half of all of the strikes for the past twenty years in America have been entirely successful from labour's point of view, 13 per cent. have partially succeeded, and only about one-third have been absolute failures; yet consider the losses.

The losses of the six million employees who were thrown out of work in that time exceed two hundred and fifty million dollars. The losses to employers and others have also probably reached that amount. The labour organisations have helped employees and their families during these struggles, it is said, by the payment of sums amounting to more than sixteen million dollars.

The great defence funds show what a capital the men can provide when called upon; but they are usually absolutely lost in a few weeks, or as many months. The amount of money spent in keeping the men and their families during the recent long Pennsylvania coal miners' strike would have purchased so large an amount of stock as to have made the strike impossible without a doubt, for the interest of the men would have been so great that the mine owners would hardly have cared to antagonise them.

Consider the quarter of a million union men engaged in the iron and steel industry in the United States, a large proportion of whom work for a single corporation. Their unions are all closely allied, and the purchase each year of a single share by each employee would represent a capital stock of two and a half million shares in ten years, with a par value of two hundred and fifty million dollars.

A single share of stock represents but little to the individual workman, and the

income from such a small amount is not at all attractive to him; but if it represents to him his life and accident insurance, his loan association and savings bank, as well as his means of defence in time of labour troubles and misunderstandings, he will look at it in an entirely different light.

This trade unionist stockholding plan may not be a cure-all for every labour difficulty, but unquestionably it is a step in the right direction. The manufacturer and capitalist may make all kinds of advances in the way of offers of stock, cash bonuses, prizes, profit-sharing and other offers of reward; but these will always be looked upon with suspicion by the men. Only when a scheme is prepared and worked out by the unions themselves, controlled by themselves entirely, and made compulsory by their by-laws, will the rank and file of the workingmen have entire confidence and pay in their assessments as regularly as they would their insurance premiums.

Workmen cannot be expected to individually make the investments on their own account, and only then will there be results worth mentioning when labour leaders begin to realise the advantages which the ownership of stock will give them, the power which it will impart, and the benefits which will come to the men through it. Only then will they take hold of the plan in earnest.

It does not require a very great stretch of the imagination, if such a plan is carried out, to look forward to a partial ownership and even control of all the greatest corporations and trusts by the men who do the work. That such results could be brought about without in any way disturbing the regular order of the business world is reasonable to suppose, while the benefits of socialism would be realised without the radical changes which community interests and a common fund would necessitate. Ultimately the labouring man would be raised to a much higher level. Various degrees of wealth will always exist as long as the capabilities of men are different; but in time, with such unionism, extreme poverty would disappear, extreme wealth of the multi-millionaire would vanish, and strikes would be no more.

THE PROGRESS IN WIRELESS TELEGRAPHY

By William Maver, Jr.

In connection with Mr. Maver's present article on wireless telegraphy it may be found interesting and profitable to refer to his earlier one in this magazine for January, 1902, in which the principal details of the apparatus employed up to that time were illustrated and described.—THE EDITOR.

THE possibility of telegraphing without wires by means of electric waves in free space was demonstrated when Dr. H. Hertz, in 1887 and 1888, holding a so-called "electric-eye," consisting of a ring of copper wire about 16 inches in diameter and broken at one point, a few feet from the spark gap of an induction coil, or oscillator, was able to detect minute sparks jumping across the break in the copper ring.

In 1889 Dr. Branly discovered that metal filings, which, when made part of an electric circuit, had normally a very high electrical resistance, but became good conductors of electricity when electric oscillations were set up in the circuit, and that they retained their conducting qualities until shaken up.

The art of wireless telegraphy took a long forward step when, in 1894, Dr., now Sir, Oliver Lodge made his notable experiments before the Royal Institution, in which he used, as a transmitter of electric waves, the Hertz or Righi

oscillator, and as a detector of those waves, the Branly coherer, consisting of a tube filled with metal filings, in an electric circuit containing an electric bell. To ensure that the filings would resume their non-conducting state upon the cessation of the electric oscillations, Dr. Lodge caused a "tapper," operated by clock-work, to strike the tube continuously. A bell or relay in the coherer circuit could thus be kept in vibration during the continuance of electric oscillations and would become passive when the oscillations ceased, and in this way signals could be transmitted. Lodge believed that the limit of sensitiveness of this apparatus would be half a mile, but even this distance advanced the signalling distance four hundredfold beyond the point at which Dr. Hertz had left it.

The art, however, received its most powerful impetus when Marconi, in 1898, using vertical wires, 80 to 100 feet high at each station, a 10-inch spark induction coil, and an improved Branly-Lodge coherer, succeeded in transmitting wireless signals a distance of about 40 miles, which distance within another twelve months, by using still higher vertical wires and more improved apparatus, he increased to 280 miles over water.

The writer on other occasions has remarked that had the progress of wireless telegraphy rested with Hertz's discovery of the copper ring detector, its utility for commercial purposes would have been very limited, in fact, nil, since the utmost distance at which signals can be detected by that device is about 8 or 10 feet. It might now, with considerable truth, be said that had the further progress of the art ceased with the discovery of the Branly filings coherer, improved as much as it might be, the commercial utility of wireless telegraphy would have been very much hampered, for not only would the utmost distance to which signalling could have been successfully carried on been limited to 200 or 400 miles, but the rate of signalling would more than likely have been kept at from ten to twelve words per minute, for the action of the filings coherer, it may be said, is inherently sluggish in the production of perfect signals, the cohering and "tapping back," together with the inertia of the moving parts of the tapper, the relays, etc., all tending to that result. Possibly the limitation to the signalling distance due to the sluggishness and lack of sensitiveness of the filings coherer could be somewhat compensated for by the use of higher masts and greater electrical energy at the transmitting station; but this would be at additional expense, and probably would also be accompanied by a further reduction in the rate of signalling.

It was, therefore, very obvious to all concerned in the art of wireless telegraphy that a thing much to be desired was the invention or discovery of a coherer or detector which would, so to speak, "close" automatically on the occurrence of electric oscillations, and "open" automatically when the oscillations ceased, or vice versa. As frequently happens in such cases, this desideratum was not very long in forthcoming.

One of the first devices that bore promise of fulfilling the foregoing requirement is known as Schaefer's "anti-coherer." This consists of a silver film deposited on glass. Across this film slits are traced, this being covered by a thin layer of celluloid. When the silver film is made part of an electric circuit it is found that the resistance of the circuit rises when electric oscillations are set up therein, and when the oscillations cease, the resistance automatically falls. This action, it will be observed, is the reverse of what occurs in the Branly filings coherer; hence the name of anti-coherer. It has been surmised that the effect of the film of celluloid which does not penetrate into the interior of the slits is to prevent the dissipation of the particles of silver in the slits, and whose motion under the influence of electric oscillations probably accounts for the variations in the resistance of the circuit. Carbon filings were also found to decohere automatically; but these devices were not extensively used in practice, if at all.

The next most important auto-coherer

was that due to Solari, known for a time as the Castelli coherer, also as the Italian Navy coherer. This auto-coherer was used by Marconi in his first experiments in transatlantic wireless telegraphy. It consists of a tube similar to the filings coherer, but instead of metal filings between the ends of the iron or carbon rods within the tube, a drop of mercury is employed. In the circuit with the coherer there is a small battery and a telephone receiver. On the arrival of electric oscillations the mercury appears to cohere to the carbon or iron, with the result that the resistance decreases, and vice versa, the variations in the resistance of the circuit setting up noises in the telephone, which can be read as dots and dashes when messages are transmitted.

Subsequently Marconi devised an auto-coherer, known as a magnetic detector, which has been used in his transatlantic and other long-distance experiments. This coherer consists of a primary and secondary wire, wound over a core of fine magnetised iron wires, the inner wire of which is connected to the vertical wire in a manner practically similar to that in which the filings coherer is connected. The outer wire contains in its circuit a telephone receiver, but no battery. This detector of electric waves is based on the observed fact that when a magnet, such as the iron core, is caused to undergo slow changes of magnetism, electric oscillations in the outer wire bring about rapid changes in the magnetism of the core, which, in turn, set up currents in the inner coil, and these are heard as clicks in the telephone re ceiver.

In the United States, De Forest and Fessenden have also devised auto-coherers which are used in their respective systems. The De Forest auto-coherer, which has been termed a "responder," comprises a tube, with the usual rods or plugs running into the bore. Between the inner ends of the plugs is placed a viscous substance, such as glycerine, in which some lead oxide is suspended. In series with the tube are a small battery and a telephone. Normally, the battery sets up an electrolytic action which causes the metal in the solution to "bridge," or "thread," over the space between the ends of the plugs, with the result that the resistance is much decreased. Incoming electric waves, however, establish electric oscillations in the responder circuit which disrupt the threads or bridges, whereupon the resistance is at once greatly increased.

These variations in the resistance of the circuit are readily indicated in the telephone, and thus when the train of electric waves is broken into dots and dashes of the Morse code, messages are easily received. This auto-coherer, it will be observed, is of the anti-coherer type.

The Fessenden detector employs a different principle from either of the foregoing. Fessenden takes advantage of the facts that an electric current increases the temperature of a conductor through which it passes, and that an increase of temperature of the conductor increases the electrical resistance of the conductor, and contrariwise. He, therefore, employs a very thin loop of platinum wire, contained in a small glass bulb, the whole so disposed that heat will be quickly conducted from the platinum wire. In the circuit of this loop he includes a small battery and a telephone receiver, suitably connected with the vertical wire. When oscillatory currents are set up in the circuits, rapid variations of the temperature of the platinum loop, and corresponding variations in the resistance of the circuit, are produced, these, in turn, affecting the telephone receiver practically as in the instances already given.

By reason of the sensitiveness of the telephone receiver, changes of current that would not affect a relay are observable in the former instrument. Hence, by the use of this instrument much weaker electric waves are detected than would be the case with the filings coherer. Furthermore, the auto-coherer responds instantaneously, so that a higher rate of signalling is obtainable by its means, a speed of forty words a minute having already been obtained by De Forest. Marconi also predicts that ulti-

mately he will be able to transmit a hundred words a minute by means of his detector and suitable automatic transmitting and receiving apparatus.

Important improvements have also been made in the matter of syntonic, or tuned, wireless telegraphy, by means of which it is hoped to eventually transmit two or more different messages at the same time to and from the same stations. Thus far it does not appear that this desirable result has been satisfactorily accomplished. By means of tuned circuits, however, the principle of sympathetic resonance is brought into use, and thus, with a given amount of electrical energy at the transmitter and a detector of given sensitiveness, it is feasible to transmit messages to a greater distance than would be the case with untuned circuits.

For long-distance transmission Marconi, De Forest, and others have successfully resorted to the use of dynamo-machines for the production of electric oscillations of much greater energy than are obtainable by the most powerful induction coils. The height and number of vertical wires used in long-distance transmission have also been augmented, towers 250 feet high, with fifty or more vertical wires, being employed by Marconi at his transatlantic stations.

Considerable progress has also been made in telegraphing overland without wires, by means of portable outfits, for military purposes, the bulk of the work of this kind having been done by Siemens & Halske, of Berlin, Germany, using the Braun system. The apparatus is transported on carts, and the vertical wire is elevated by means of a captive balloon, or, in fair weather, by kites. The distance to which signals can be transmitted by this apparatus is said to be sixty miles, and it is anticipated that within a short time all the important armies of the world will be supplied with apparatus of this general type. It may be added here that the United States Government has equipped six stations with the De Forest wireless telegraph system for the use of the signal corps of the United States Army.

The most important commercial use to which this art has yet been put, however, is that of making possible communication between vessels at sea and between vessels and the mainland, which would still appear to be its greatest sphere of usefulness, and every week sees a larger number of vessels equipped with wireless telegraph outfits. Indeed, as someone has well said, every vessel not so equipped has a grievance.

Current Topics

A YEAR ago an account was given in these pages of a special exposition, held about that time at Berlin, of apparatus, machinery and products which typified the manufacture and technical uses of alcohol in Germany. That exposition was held under the joint management of two national organisations, the Union of Alcohol Producers and the Association to Promote the Industrial Uses of Alcohol. This year a similar exposition was held in the same location and under practically the same management, but with a much wider scope, in that it included all that related to the culture and economic use of the potato, as human food, as feed for domestic animals, as material for the manufacture of alcohol, and as material for starch and subsidiary products,—starch sugar, sirup, dextrin, etc. Whereas the exhibition of 1902 covered one varied and interesting phase of the economy of the potato in Germany, the display of 1903 thus included four distinct departments, which collectively covered and illustrated with surpassing completeness and interest one of the most important branches of German agriculture and its dependent industries. From a report on the exhibition of this year, made by Consul-General Frank H. Mason, it appears that the department of lighting apparatus included a vast and varied display of lamps, chandeliers, and street and corridor lights, in which alcohol vapour is burned like gas in a hooded flame covered by a Welsbach mantle. Under such conditions alcohol vapour burns with an incandescent flame which rivals the arc light in brilliancy and requires to be shaded to adapt it to the endurance of the human eye. There has been since last year a great improvement in the artistic models and finish of lamps and chandeliers for alcohol lighting. At the beginning they were simple and of rather ordinary appearance, but now they are up to the best standard of modern fixtures for gas and electricity, with which alcohol lighting is now competing with increasing success in Germany.

SIMILARLY attractive and interesting was the large display of alcohol heating stoves, which, for warming corridors, sleeping rooms, and certain other locations, are highly esteemed. They are made of japanned iron plate in decorative forms, with concave copper reflectors, are readily portable, and, when provided with chimney connections for the escape of the gases of combustion, furnish a clean, odourless, and conve-

nient heating apparatus. Cooking stoves of all sizes, forms, and capacities, from the complete range, with baking and roasting ovens, broiler, etc., to the simple tea and coffee lamp, were displayed this year in endless variety. This entire department,—the use of alcohol for household purposes,—was ably and efficiently managed by the Central Association for Alcohol Distribution, which keeps a large depot in Berlin and other German cities, where every kind of alcohol lamp, burner, heater, cooking apparatus, toilet fixture,—everything that can use denaturised alcohol,—is kept on sale at retail or to the trade.

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As another example of the efficiency of this organisation may be cited its system of alcohol distribution to rural districts as a convenient fuel for motor purposes. Since the inception of this movement, it has been a point of extreme importance to replace the steam locomobiles for thrashing, grinding, fuel cutting, and other agricultural purposes with alcohol motors, for which are claimed the important advantages of immediate readiness for operation, no coal or water to be provided, no fireman needed, freedom from smells or danger of fire, and, finally, greater economy of maintenance. But in order to promote the substitution of spirit motors for steam and horse-power, it was necessary to make alcohol cheap and easy to obtain by farmers in districts where no raw spirit is made. To meet this requirement, the Central Association undertakes to deliver free at any railway station in Germany denaturised alcohol of 90 per cent. purity, in quantities of 180 to 200 liters, for 15, 16½, and 17½ pfennigs per liter (approximately 15, 16, and 17 cents per gallon), according to the material with which it is denaturised. As the consumption of a modern alcohol motor for farming purposes is about 0.5 liter (costing about 2 cents) per horse-power-hour, it will be apparent that in Germany at least benzine and petroleum have met a serious competitor as fuel for motor purposes. The Hamburg-American Steamship Company has in service a harbour-inspection launch, which, with a 23 horse-power spirit engine, makes a speed of 10 knots, and preparations are being made to greatly extend the use of such motors in the launches and ships' boats of the German navy. This is understood to be the case also in the Russian navy, in which alcohol boat motors are said to have been under trial for two years past with very satisfactory results.

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In discussing miscellaneous sand-blast uses recently before the American Society of Civil Engineers, Mr. H. B. Seaman mentioned one point which does not thus far seem to have received due attention, and that is that the excessive use of the sand-blast in cleaning iron and steel, especially where the rust is slight and where part of the surfaces is covered by elastic paint, may prove more injurious than the rust. The sand-blast will remove the rust quickly; but if continued long enough to remove the elastic paint, which requires considerably more time, the parts which were rusted will be worn deep and pitted, and when the whole surface is bright and smooth, and acceptable to an enthusiastic inspector, more metallic iron or steel may have been removed than would be the case after several ordinary coats of rust. Furthermore, the naked metal, as left by the sand-blast, will rust much more quickly than when the mill finish is left. An illustration of the danger of overdoing the sand-blast occurred recently, under the supervision of an ardent, but well-meaning, inspector. Four columns, which had been similarly exposed to the weather, while stored in the same pile awaiting erection, were brought out and laid side by side to be cleaned by the sand-blast. After three and one-half hours of the sand-blast, two of these columns were stripped absolutely clean of rust and paint, and of all sign of the original mill surface; finished, in fact, clean enough for electroplating. The work could not have been done more thoroughly if per-

formed in a laboratory for experimental purposes. The remaining two columns were then cleaned of rust and dirt, but all good paint was left on. This required forty-five minutes, and the columns were left in better condition than the first two, at about one-fourth of the expense.

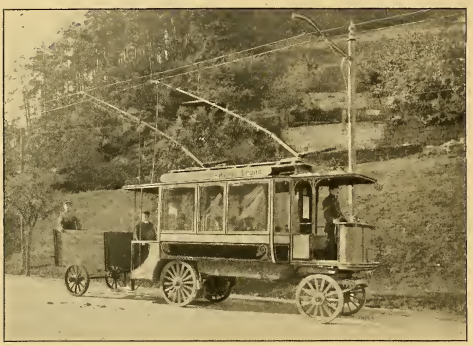
THE theory that iron must be cleaned to a white surface before being painted does not seem tenable. The thin coat of black oxide, formed after rolling, is itself a valuable protection, being the most permanent form of iron oxide, and even when the iron is tinted brown with rust, it is not clear why the paint which would protect the iron from rusting will not in like manner prevent the rust from progressing, excepting, of course, where the rust is so thick as to prevent adhesion of the paint to the iron. Where the sand-blast is used, it is necessary to paint at once to prevent corrosion. Aside from the commercial or scientific value of sand-blasting, there is a very serious question of its effect upon the eyes and lungs of the operator. Its use in connection with bridge shops would seem not only objectionable on account of its disturbing effect upon the other operations, but, as already mentioned, because it removes the black oxide of manufacture, which is the natural protection of the metal. Any scale which may be formed after rolling is quite thoroughly removed in punching and handling through the shops.

THE use of reheaters in compound engines was the subject of an interesting paper recently read by Mr. George H. Barrus before the New England Cotton Manufacturers' Association. The principle on which the action of the reheater depends is the re-evaporation of the water and moisture contained in the exhaust steam discharged from the high-pressure cylinder, and further, in cases where the extent of reheating surface is sufficient, the superheating of the whole quantity exhausted. The result is two-fold; first, an increase in the relative amount of power developed by the low-pressure cylinder on account of the new supply of steam produced; and second, the use of the steam with increased efficiency, owing to the saving of cylinder condensation due to its dryer condition. The reheater tests to which Mr. Barrus referred showed these actions in detail, and were made on three independent engines. In each case one test was made with the reheater in complete operation, and one with the heating pipes shut off, which practically threw the reheater out of use.

THE results of the tests showed that the consumption of feed-water was in all cases practically the same whether the reheater pipes were in use or out of use; but, still, if the condensed steam from the reheater were returned to the boiler, instead of being allowed to go to waste, there would be a saving of fuel. Apart from these considerations, however, it is to be noted that the reheater has a most important bearing upon the capacity of the engine. The tests showed, without exception, that with the same power in the high-pressure cylinder, the reheater produced a considerable increase in the power of the low pressure cylinder, and to that extent it increased the capacity of the entire engine. The average increase for three cases under trial was slightly over 7½ per cent. This means that an engine without reheater must have larger cylinders to do the same work than an engine with reheater; or, if the cylinders are of the same size, there is more reserve power in the engine which is provided with a reheater. This feature of the subject makes the reheater advantageous even if it produces no other gain.

WHILE experiments with electric carriages for ordinary road use, taking the current from overhead electric light or power wires, were commenced in the

United States eight or ten years ago, very little has been done with them there, owing possibly to the quiet opposition of trolley roads and other electrical interests. In France and Germany, however, where the conditions have been more favourable in a number of respects for "trackless" trolleys, or, in other words, where the objections to rails on the prevailing narrow streets are greater, a number of such trolley lines are in successful operation, special wires being erected for the purpose. Inasmuch as a ground wire is not available in the absence of rails, the carriages are rubber tired, and the double-trolley wire system is employed. Contact in some instances is made with the overhead wires by means of two trolleys connected by a flexible cable with the car. As there is but one pair of overhead wires, it is necessary when carriages pass each other to change the cable connections from one car to the other. On other systems two trolley rods with sliding contacts are utilised on each carriage.



THE "TRACKLESS" TROLLEY IN GERMANY, AS EQUIPPED BY MESSRS. SIEMENS & HALSKE, OF BERLIN. SINCE THERE CAN BE NO RAIL RETURN, THE DOUBLE-TROLLEY SYSTEM MUST BE USED

Interesting examples of both kinds of equipment are shown in the illustrations on this page, both of the outfits having come from the works of the well-known German electrical firm of Siemens & Halske, of Berlin. Both direct current and polyphase current are used in this service. The speed of these trackless carriages is about fifteen miles in the open country, and freight and express trucks, as well as passenger cars, are operated.

In a recent report on the utilisation of lignite, peat, and coal-dust fuel in Germany, Consul-General Frank H. Mason, at Berlin, gives some interesting particulars of what is being done in that country with compressed peat and peat coke. Peat as a material for fuel ranks next in natural order below lignite, in that it is of similar but much more recent geologic origin, contains more water, is but slightly carbonised, and has a corresponding lower thermal value than brown coal. The task of converting peat into serviceable fuel consists in cleaning the material of roots and rubbish, reducing the water to a small per-

A FLEXIBLE CABLE CONNECTION HERE SUPPLIES THE CARRIAGE WITH CURRENT FROM THE OVERHEAD WIRES

centage, and so condensing the peat in volume that its thermal value shall be raised to practical efficiency. A pioneer in the invention of machinery and processes for making compressed peat in Northern Europe appears to have been Mr. C. Schlickeysen, of Rixdorf, near Berlin. His first two machines were of vertical construction, and were built in 1859 for a steam peat-compressing plant at Zintenhof, near Riga, in Russia, where they worked successfully for many years, turning out daily about 80,000 pieces of wet compressed peat, which, after drying, were used as smokeless fuel in a large cloth factory at that place. During the ensuing forty years he has built peat-compressing plants in Holland, Hungary, Switzerland, and at various places in Germany, constantly improving his equipment and processes with a view of perfecting the product, cheapening its cost, and substituting more and more automatic machinery for manual labour.

RAW peat, as it comes from the bog, contains about 85 per cent. water, 13 per cent. combustible material, and 2 per cent. inorganic matter. To obtain the 13 per cent. of combustible elements in the cheapest and most direct manner, the peat is cut with spades and shoveled into the trough of a long, sloping belt-and-bucket elevator. This carries it to a machine which cuts, tears, kneads, and mixes it to uniform consistency, in which state it is forced out by a horizontal screw into long, plastic skeins about 3 by 4 inches in transverse section. These are delivered at the tail of the machine on boards 3 feet long, which are lifted off by hand when filled, laid on tramcars, and run out to a cleared space, where they are laid in rows on the ground, and the skeins are cut with a knife into bricks or sections 10 inches long, which, being left to dry, lose, by exposure in ordinary weather, one-half their water contents in a period of two weeks. The peat loses by this machine process one-third its bulk, so that a machine which works, say, 600 cubic feet of raw turf per hour delivers 400 cubic feet of clean peat, or 7000 wet bricks, of the size indicated, which contain from three to four tons of dry compressed peat in a condition to be used as fuel.

A PLANT of this kind includes, besides the elevator and grinding press, a 10 horse-power portable engine, which is fired with peat refuse, and cars and tracks for handling the material. The whole plant is movable, is taken bodily to the bog, set up at the farther edge of the moor to be worked, and moved backward as the peat bed is excavated and exhausted. An important recent improvement by Mr. Schlickeysen is an excavating machine, which in moors reasonably free from logs and stones, digs and elevates peat with great rapidity, thus saving the hard, wet, unhealthy work of several men. After air-drying on the ground until their water contents are reduced to 38 or 40 per cent., the peat blocks are built up in open formation, like bricks in a kiln, to dry until the water is reduced to 15 to 18 per cent., when they become a fuel with a thermal value of from 12,000 to 16,000 British thermal units. This value may be increased by converting the air-dried peat into briquettes, which is done by heavy pressure with heat in a machine press specially constructed for the purpose. One of the important improvements of recent years has been attained by mixing the peat pulp, as it passes through the grinding machine, with other inflammable materials, viz., bituminous coal dust or slack up to 30 per cent., anthracite culm up to 40 per cent., or dry sawdust to 15 per cent. These dry, pulverised materials, when mingled with the wet peat, not only greatly enhance its subsequent value as fuel, but facilitate the drying process and render it tough, dense, elastic, and capable of being pressed cold into bri-briquettes of high quality.

BUT by far the most modern, scientific, and rational method of utilising peat appears to be that of converting it

into coke, by carbonisation in retort ovens with recovery of the gas, tar, and other by-products of distillation. This has been the subject of many years' study and experiment in Germany, the best results of which have been embodied in the system perfected and patented by Martin Ziegler, a chemical engineer of high reputation, which gives to the manufacture of peat coke the dignity of a perfected industrial process. Concisely stated, the Ziegler method consists in carbonising peat in closed ovens, heated by burning under them the gases generated by the coking process itself. Such a plant is, therefore, self-sustaining, the only fuel required being coal or wood sufficient to heat the oven for the first charge, when the gases generated by the coking process become available and enable the operation to be repeated and continued indefinitely. Not only this, but the waste heat from the retort furnaces passes on and heats the drying chambers in which the raw, wet peat is prepared for the ovens by drying to the point of economical carbonisation. The peat coke produced as the primary product of this process is jet black, resonant, firm, and columnal in structure, pure as charcoal from phosphorus or sulphur, and, having a heat value of about 28,000 British thermal units, it is so highly prized as a fuel for smelting foundry iron, copper refining, and other metallurgical purposes that it readily commands from forty to fifty marks per ton. It is also a high-class fuel for smelting iron ores, but as the process is comparatively new and the output limited, it is as yet too scarce and expensive for blast-furnace purposes. Crushed and graded to chestnut size, it forms an excellent substitute for anthracite in base-burning stoves. In larger lumps, as it comes from the oven, it fulfills substantially all the various uses of wood charcoal as a clean, smokeless fuel. This process is in successful operation at Redkino, in Russia, and the German Government has evinced its practical interest in the subject by placing at the disposal of the company a large tract of peat-moor lands, the property of the State, on which extensive works will be erected during the coming year.

HEATING a factory building, in part at least, with the hot exhaust gases from a gas engine, has apparently been satisfactorily accomplished in a case described in a recent issue of *The Engineer* by William O. Webber. The engine is situated in a pit, so that it is practically below the street floor of the building. The escaping gases from the cylinder of the engine are led through a horizontal return-tube feed-water heater of the condenser type. This heater is situated sufficiently below the street floor, so that the returns from the hot-water system, passing under the lower floor, just enter the under side of the heater. The riser from the upper side of the heater passes close under the floor, and is then led up into the building. The amount of heat which is transferred to the water in the hot-water heating system is controlled by closing the valve leading directly into the chimney from the gas engine, opening the valve admitting gas into the upper half of the return flue heater, and throttling the outflow of gas from the under side of the feed-water heater; or if no heat at all is required in the building, the valves leading to the heater are both closed, and the gases are allowed to escape directly up the chimney. In order to properly distribute the gases throughout all of the tubes of the feed-water heater, the exhaust from the engine, which is 2½ inches, was enlarged to 5 inches for about 30 inches just before reaching the heater. A perforated baffle-plate having a sufficient number of small holes punched in it to equal the area of the 2½-inch pipe, was clamped between the flange on the heater and the flange on the 5 inch pipe. This section of 5-inch pipe was then filled with pieces of fire-brick broken to about the size of a hen's egg. This device, besides distributing the gases into the flues of the heater, also acts as a muffler, and seems to work very efficiently. During the past winter the load on the

gas engine did not require enough gas to provide heat for the whole building, and an auxiliary hot-water heater was, therefore, in use, coupled to the same circulating system. This heater served also for warming parts of the building on Sundays and holidays when there was no demand for power, and no heat, consequently, was to be had from the gas engine. The performance of this combination system, according to Mr. Webber, came fully up to all expectations.

ONE of the greatest advantages of the steam turbine, and yet one to which comparatively little prominence has hitherto been given, is its economy of floor space. Both afloat and ashore this counts for much. In connection with electric power station equipment, for example, the statement has been made, according to a recent paper by Mr. H. A. Lardner before the American Institute of Electrical Engineers, that the Westinghouse-Parsons turbine requires about 80 per cent. of the space needed for a vertical, and not over 40 per cent. of that required for a horizontal engine. This statement is based on a station layout with a clear space of 7 feet in all directions between machines. This type of turbine being horizontal, requires less head room and consequently a cheaper building by a considerable amount than the vertical engine. Tabulated data show the required building capacity for such turbines to be about 50 per cent. of that needed for vertical engines.

A LATER comer in this field is the Curtis turbine, controlled by the General Electric Company, of New York. This is of the vertical-shaft type, and while it requires more head room than the Westinghouse-Parsons machine, it is still more saving in the matter of floor space. The following tables will here prove interesting, giving the principal dimensions of some of the sizes which are now being built:—

CURTIS TURBINES AND GENERATORS

Size KW.	Height ft. in.	Diameter ft. in.	Floor Space sq. ft.	R. P. M.
500	12 2	7 8	46.2	1800
1500	16 10	10	78.5	900
3000	22	14	154.	600
5000	27	14 10	175.	500

WESTINGHOUSE-PARSONS TURBINES AND GENERATORS

Size KW.	Height ft. in.	Dimensions ft.	Floor Space sq. ft.
400	7 6	19 x 5	95
1000	8	43 x 8	344
5500	15	50 x 12	600

For comparison, the following is the floor space required by the vertical cross-compound condensing engines of a well-known maker. The figures include the space required for an alternating-current generator between the frames:—

Size KW.	Dimensions ft.	Floor Space sq. ft	R. P. M.
500	15 x 22	330	120
1000	21 x 24	504	110
1500	22 x 28	616	100
2500	23 x 32	736	90
3000	23 x 34	782	75

The height in all sizes thus exceeds that of a similar size of vertical turbine.

So much persistent effort has, in recent years, been expended in cutting down boiler and engine weights on warships,—and not always for the best of the service,—that to the naval engineer there must be a good deal of satisfaction in reading a recent paper presented to the Institution of Naval Architects by W. H. Whiting, Assistant Director of Naval Construction of the British Navy, dealing with "The Effect of Modern Accessories on the Size and Cost of Warships." The substance of Mr. Whiting's paper is that there are a hundred and one different ways, and many of them not very useful ways, in which the weight of a modern warship has been increased. Few of them have anything to do with the propelling power of the ship, and all of them might be carefully scrutinised and revised with the certain result of advantageously lightening the ship by a great many thousands of pounds. The fondness for unnecessarily heavy brass fittings of all kinds, for example, has often been mentioned as one of the things which might well be restricted, and while this is only

a little thing in itself, it is the little things which count severely in the aggregate. Take so insignificant a matter as paint, for illustration! Mr. Whiting says that one who has not the records before him may well be incredulous at the enormous weight of paint worked into a ship. The most serious feature is that the process never ceases, and the greater the pride in the ship, the greater the tendency to sink her with white lead. He mentions a case in which there was removed from the inner surface of a portion of the crew space of a destroyer paint of a weight of over two pounds per square foot. This is, no doubt, exceptional; but it may well be questioned whether all officers realise how, by a rigid economy in paint, they may not inappreciably benefit their ship. A curious development, further, has been the desire for screw gear on board ship. Not merely in rigging, but in many fittings, such as awnings, ridge-ropes, guard-chains and ropes, and in the securing of all kinds of gear, lashings have given place to screws and slips, which not only add directly to the weight, but impose greater strains on the fittings. The screws mean bigger awning, stanchions, and so on.

With reference to larger details, Mr. Whiting points out that the higher standard of life ashore and afloat adds rapidly to the weights of warships. The provision for food, cooking, bathroom, and sanitary fittings, ventilation and artificial light has greatly increased in the last twenty years and is still increasing. A large proportion of the complement needs superior accommodation, corresponding with their higher training. The weights of tiling and of piping for hot and cold water are vastly greater than those that served for many ships which are still in commission. The steam or electric motors used for operating different kinds of labour-saving appliances involve a heavy coal bill, so that to give a ship a specified steaming capacity it is necessary to add a much larger percentage of coal than formerly. This load has to be carried at the given speed. The distrust, or, rather, the partial trust, of new appliances, too, adds largely to weight and cost. Candles or lamps give place to electric light, but the fear of losing the light involves the carrying of two systems instead of one. So it has been with sail and steam power, steam and hand steering, hydraulic gun gear and hand gear. And as it is but rarely that the new appliance has an advantage in every conceivable circumstance over the old, there is a great tendency to carry both. In almost every case such duplication involves some new chance of a breakdown. Then there is the tendency towards duplication of fittings. There are two steering engines, or two leads of shafting to operate the steam-steering engine; the dynamos are designed so that one may always be under repair or idle; and each of the hydraulic pumping engines is equal to the whole demands of the armament. Here, too, the cause of the demand for the increased weight is the difficulty of saying exactly what risk should be accepted. The logical course would be to make provision proportional to the magnitude of the risk multiplied by its probability. It is possible that in some cases an approximate valuation might be obtained by careful study, and Mr. Whiting suggests that no small service might be rendered to the Navy by an examination of this question. Only a few of the points raised in the paper have here been mentioned, but these serve well to indicate the lines which it follows.

In the very large quantity of printed matter that has been put out on the subject of training engineers, there is little that so squarely presents the really vital point at issue as the following from a recent two-column editorial in the London *Engineer:* "Engineering knowledge," says the *Engineer*, "is a means to an end. That end is the making, not of mechanism, but of money. The construction of machinery is simply an incident in a complex process. This

simple issue is constantly obscured. The ingenious youth passionately devoted to mechanics does not for a moment associate the designing and building of steam engines with any commercial ideas whatever. He does not know, and he does not care to know, what a big locomotive or a fine pair of marine engines cost. Price is to him of no importance; no sordid thought of that is permitted to degrade science. On the other hand, the professor is just as ignorant of shop charges, the price of materials, or the cost of labour. He deals with the scientific aspect of the whole question. Thermodynamics is not a matter of pounds, shillings and pence; entropy, if it has to do with everything else, at least has no concern with rates and taxes. The strength of boiler plates is the professor's affair; with the price of boiler plates per ton he has nothing to do. When a young man gets into the shop or the drawing office, no one directs his attention to costs. A man may spend six months in a foundry without knowing what pig-iron is worth per ton, or the value of the coke burned week by week in the cupolas. From first to last the all-important part of an engineer's training is left out of consideration.

"THE professor should keep before him continuously the axiom that the training of his pupils should be just that which will confer the maximum power of making money. It may be said by a few that this is a very sordid view to take. It is absolutely nothing of the kind; and the professor who knows his work will be the first to maintain that really the higher the training, the greater is the pecuniary value of the finished student. Opinions will differ on this subject; but we cannot for a moment admit that in the present day the parent is sordid because he knows that his son has taken up engineering as a profession for the same reason that another son has taken up medicine, or a third has emigrated—namely, to earn his bread; and the parent will be justified in insisting that none of the limited time available shall be wasted in the acquisition of knowledge which will be subsequently of no pecuniary value whatever. It may be good for a man to know how to calculate eclipses, but the knowledge is not a universally marketable commodity. Every young engineer is supposed to have something which he can sell. His whole scientific training has been intended ostensibly to supply him with commodities which he can put on the market. To fill his pack with that for which there is no demand is to commit a deplorable error. To avoid falling into it, it is essential that all those engaged in teaching should understand precisely what it is the mechanical engineer, or the civil engineer, or the electrical engineer ought to know, and to the end that this understanding may prevail where it is needed, we maintain that every professor who teaches engineering should not only have gone through the shops or have been engaged on practical work as a civil engineer, but that he too should adopt the 'sandwich' system and find employment in works, just as his pupils do when the college terms end. In no other way than this can he keep himself fully in touch with the practical developments of engineering which are going on day by day. In no other way can be acquired those sound ideas of commercial work which it is essential he should be able to impart to his pupils. After all, even professors have something to learn, whatever their pupils may think."

THE criticism is well made by a correspondent in a recent issue of the *American Machinist* that the special features which constitute the talking points or the selling points of many modern machine tools are often unduly magnified in importance, and that shops are loaded with tools possessing special features which are excellent, but which seldom or never come into play where the tool is employed. A lathe which does not have a screw thread to cut once a month is not much helped by a handy arrange-

ment for changing the lead gears or which gives the entire range of changes by the mere shifting of a lever. Taper-turning attachments are serviceable for taper-turning, but they are of no value, indeed just the reverse, on a lathe which never has any taper work to do. It happens quite often that the new machines are not selected by the man of the establishment who has the best mechanical judgment or experience, but by the one who knows how to get the greatest value for the money. What he often gets is the most costly thing for the money, which may be very different from the thing that would be of the greatest value to the shop. In shops of considerable size where there are quite a number of standard machine tools of each class,—lathes, planers, shapers, millers, drills and the rest,—it never happens that each of these tools is employed on a great variety of work. They each settle into their regular and narrow lines and rarely do anything else. For doing this precise work they should, of course, possess every possible facility; but what will it avail them beyond that to be able to do things that it will never be possible for them to get a chance to do? Most buyers of engine lathes would, of course, never think of buying a lathe without the full screw-cutting apparatus, and yet we know that as lathes go not one-quarter of them ever cut a thread. It is a good deal the same with the ability to make big chips; what is the use of it if you can't get any big chips to make? If an athlete is going in for a race, he always strips for it. We don't seem to be going in much for stripping our machine tools, yet why not? Some day, perhaps, some machine-tool builder will arise with enterprise enough to advertise that his normal lathe is the stripped lathe, adapted to do the plainest work and the most of it, and that the special eatures required will be furnished when they can be of use, but are not recommended where they cannot be used. The cheapness that is secured by the discarding of the useless and the redundant is to be commended. It is well always to remember that the machine which can do the greatest variety of work can never do any of it as well or as rapidly as the special tool for the individual job.

Those who, being somewhat familiar with the electrical nomenclature employed in ordinary scientific and commercial electrical pursuits, and having perhaps had occasion to peruse the mystifying papers of eminent physicians on almost any branch of electro-therapeutics—mystifying on account of the use of unfamiliar electrical terms—must have learned with pleasure that a committee on current classification and nomenclature, composed of well-known electrical engineers, had been appointed by the American Electro-Therapeutic Association in 1901, "to investigate the nature of the currents used in medical practice, and to suggest adequate or appropriate terminology therefor." This committee, which consists of Dr. Elihu Thomson, Dr. Samuel Sheldon and Mr. William J. Jenks, recently made a tentative report in which the members of the committee confined themselves to the formulation of a scheme of nomenclature to which they invite "the most general and intelligent criticism and suggestion." In this report the committee first classify and define currents with respect to their prime electrical source, as follows:—Voltaic current,—a current primarily due to a voltaic battery, storage battery, or other electro-chemical source; static current,—a current primarily due to an electrostatic (influence) or frictional machine; dynamo current,—a current primarily due to a dynamo-electric machine, whether having permanent magnets or electro-magnets; dynamo-static current,—a current primarily due to a dynamostatic machine; thermo-current,—a current primarily due to a thermo-battery, or thermo-pile. The report then goes on to classify currents with respect to secondary electrical generating or modifying apparatus, amongst which the committee mention and define, at considerable length, and with the aid of numerous diagrams, induced current,

reaction current, shunted current, oscillated current, unsymmetrical-wave current, and others. It is noteworthy that not once in the report are mentioned those terms so dear to old-time practitioners, namely, faradic and galvanic currents. Galvanic batteries are mentioned once, perhaps by a slip of the pen, where, under the committee's own definition, voltaic is the preferable term.

SPEAKING of the continuous and mysterious corrosion of condenser tubes in steamships for which it has often perplexed the minds of their engineers to find a cause, Mr. A. W. Stewart recently remarked before the Institution of Naval Architects that, as something had to be blamed, the currents from the ships' electric lighting systems have usually served the purpose. Many ships have been double-wired throughout to try and cure this trouble, but with no improvement; and in the course of Mr. Stewart's own professional work several cases had been given him for investigation. One case that occurred will help to illustrate the many curious causes of corrosion. A Channel steamer, wired on the single-wire system, and about one year old, suddenly gave trouble in her condenser tubes, most of the tubes being so bad as to require renewal. The engineer blamed the electric light, but on being convinced that this could hardly be the case, he blamed the manufacturers of the tubes, who accepted the responsibility and supplied new tubes free of cost. It was learned that a paddle steamer about twenty years old, whose condenser tubes had never given any trouble before, suddenly developed serious corrosion,—no electric light being fitted to this steamer. On making inquiries, it was ascertained that the two steamers had been moored together about six weeks previously in a certain part of a river not famed for its purity. Further inquiries elicited the fact that they were lying close to a main sewer pipe, which also served as the discharge from a galvanising works, where many acids were used and discharged; hence, the cause of the condenser tube troubles. In some instances steamship companies had adopted double wiring in the hope that they would get over condenser tube troubles, and in one or two cases, which may be put down to coincidence, the double-wired ships turned out to be worse than single-wired ships. One of the largest steam tugboat companies, with no electricity of any description in their ships, was particularly badly affected in this respect. As regards abnormal corrosion in condenser tubes, Mr. Stewart's opinion is that the cause is more likely to be due to the presence of impurities left inside the tubes by the circulating water than by an impure quality of brass used in the manufacture of the tubes.

A UNIQUE system of profit sharing, in vogue in the works of the A. S. Baker Company, a Western firm manufacturing pumps and windmills, is described by the Rev. George L. McNutt, in the *Independent*. The plan is said to have been in operation for two years with good results, economic and social. The following are the salient features, as described by Mr. McNutt:—As a beginning, each man who had been in the company's employ during the past year was given a bonus of 10 per cent. on his wages. Meanwhile, the business of the company was enlarged by increasing the capital stock to $300,000. Of this, $200,000 were preferred stock, fully paid up, and $100,000 to be issued in profit sharing between labour and capital in proportion to the earnings of each, the earnings of capital being arbitrarily fixed at 5 per cent. on preferred stock, and the earnings of labour being the amount earned by each employee on day wages or salaries during each year. The money paid to stockholders as dividends and the money to labour as wages is in each case treated as for practical purposes earnings on capital. The capital of the stockholder is the total of money invested, and the capital of the labourer is the total of his strength, his character, his skill, — these three, muscle, brain, soul or self. Money

capital is paid a yearly dividend of 5 per cent.; man capital is paid the current wage of a given trade. Money capital and man capital being equals in the eye of the law of the company, it is a simple problem in percentage to reckon up the man capital of a labourer from his yearly wage. Divide by five, multiply by 100. A $500 a year common labourer is a $10,000 man. The year's dividends to money having been paid, 10 per cent. of the remaining earnings are put aside into a rainy day sinking fund. The remainder is now ready for division between the two capitalists, the money and the man, "according to the earning capacity of each." One skilled mechanic at the bench said recently that his profit over and above his wages had been $725 in one year. This is paid, according to the by-laws, 15 per cent. in cash and 85 per cent. in common stock.

ELBERT H. GARY

Chairman of the Board of Directors of the Allis-Chalmers Company

A BIOGRAPHICAL SKETCH.

ENGINEERING has been largely subdivided, of late, into specialties. There are no longer simply the broad classes of civil engineering and military engineering, but mechanical and electrical engineering, as well, and such other classifications as hydraulic, sanitary, and domestic engineering, and many others, not the least interesting and important of which, in recent years, have been social engineering, so-called, having for its object the harmonising of interests of employers and employees, and financial engineering, — this a more fanciful term, perhaps, but suggestive of one of the very essential requisites of conducting large industrial enterprises.

In the capacity, then, of what might not inaptly be termed financial engineer Mr. Elbert H. Gary, the chairman of the board of directors of the Allis-Chalmers Company, of Chicago, is chiefly interesting to readers of CASSIER'S MAGAZINE; hence the frontispiece portrait of him in this issue. Mr. Gary was born in 1846, at Wheaton, Ill., graduated from the law school of Chicago University in 1867, and in that year was admitted to the Illinois bar, and to the bar of the Supreme Court of the United States in 1878. For two terms he was Mayor of Wheaton, and for a period of twenty-five years he conducted a successful law practice in Chicago, serving during that time as counsel for several railways and other large corporations.

In 1898 he retired from practice to accept the presidency of the Federal Steel Company, which at that time was one of the largest industrial aggregations in the United States, and capitalised at $200,000,000. In 1901 the Federal Company became part of the United States Steel Corporation, in which Mr. Gary became chairman of the finance committee. When, in 1902, the E. P. Allis Company, of Milwaukee, and Messrs. Fraser & Chalmers, of Chicago, combined to form the Allis-Chalmers Company, with headquarters at Chicago, he was made chairman of the board of directors of the new company, and that office he now holds among his several others.

PHOTO BY W. CROOKE, EDINBURGH

THE LATEST PORTRAIT OF MR. ANDREW CARNEGIE, TAKEN SHORTLY AFTER HIS RECENT ELECTION TO THE PRESIDENTIAL CHAIR OF THE IRON AND STEEL INSTITUTE

INDEXED

CASSIER'S MAGAZINE

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CAPITAL AND LABOUR HARMONY

PARTNERSHIP AND PROFIT-SHARING PLANS

By Andrew Carnegie

In his recent inaugural address as president of the Iron and Steel Institute, Mr. Carnegie devoted himself almost entirely to the subject of employers' relations with wage-earners, and as a concrete example of how successfully capital and labour interests may be made almost synonymous, he cited the operations of late years of the Carnegie Steel Company, in which the partnership idea has been developed to the highest degree, where its ablest men are concerned, and of the United States Steel Corporation, in which the profit-sharing plan has been carried into far-reaching effect among the whole body of men in the company's service. In this plan the idea has been to evolve a species of labour-capitalist not unlike the one of whom Mr. Frank C. Perkins wrote in the June number of this magazine, and the way in which this scheme has already been taken hold of by the men is full of encouraging augury. That portion of Mr. Carnegie's address which relates particularly to this enterprise is here reprinted.—THE EDITOR.

THE Carnegie Steel Company had not gone very far in manufacturing before discovering that perfect management in every department was needed, and that this depended upon the men in charge. Thus began the practice of interesting the young geniuses around us, as they proved their ability to achieve unusual results,—the source of big dividends. These received small percentages in the firm, which were credited to them at the actual cash invested, no charge being made for good-will. Upon this they were charged interest, and the surplus earned each year beyond this was credited to their account. By the terms of the agreement, three-fourths of their colleagues had the right to cancel it, paying the party the sum then to his credit. This provision was meant to meet possible extreme cases of incompatibility of temper, or of the recipient proving incapable of development, or of enduring prosperity. At death the interest reverted to the firm at its book value. The young men were not required to assume any financial obligation, and not until their share was fully paid by the profits, and there was no further liability upon it, was it transferred to them. Thus thoughts of possible loss never prevented concentration upon their daily duties. They were not absorbed in the daily quotations, for their shares were not upon the Stock Exchange or transferable. This policy resulted in making some forty odd young partners, a number which was increased at the beginning of each year.

By this plan they were rapidly paying for their interests and promising to become the millionaires of the then seemingly somewhat distant future, which, however, proved not so very distant. They are now rich men. You will not

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fail, however, to note that the plan kept them all in excellent training, as poor men still living upon their salaries, millionaires in *posse*, indeed, but not in *esse*,—quite a difference, for millionaires seem liable to develop when still very young so many hitherto unsuspected weak spots in their constitutions requiring careful nursing, and many absences and short hours, and a dozen other impediments to hard, continuous exertion, that it does not seem good for their robust health that they should be unduly burdened before reaching middle age. The zest of the chase is over too soon. It will be found the exception when a millionaire employee strains himself unduly by over-exertion in the mill or office, nor should he be expected to do so. He has earned the right to some leisure for self-improvement. When a man has achieved a competence new duties to his family and to himself arise. Money is properly only the means to an end.

We did not fail to see, as the works enlarged, how much success depended upon the mechanical men, the superintendents and foremen, yet not one of these had up to that time been admitted as partner. The business and the mechanical men,—office and mill,—were still widely separated. Well do I remember the first attempt to bring these two departments into closer relations. It was made with our Captain Jones, well known and appreciated as in the foremost rank of managers, perhaps the foremost of his day in America. He came to us as a working mechanic at eight shillings per day. I explained to the Captain how several of the younger men in the business department had been made partners and were actually receiving much greater rewards than he, while his services were at least equally valuable, and informed him that we wished to make him a partner. I shall never forget his reply:—

"Mr. Carnegie, I am much obliged, but I know nothing about business, and never wish to be troubled with it,—I have plenty to trouble me here in these works. Leave me as I am, and just give me a thundering salary."

"Hereafter," I said, "the salary of the President of the United States is yours, Captain," and so it remained till the sad day of his death. My seniors, the presidents of the other manufacturing concerns, did not fail to take me to task for ruining the steel business by paying a mechanic more salary than any of them received. Being much the youngest of these great dignitaries, I humbly confessed my wrongdoing, not, however, failing to inquire if they knew where we could find two or three more Captain Jones's at double the price. We did not overpay the Captain; he was worth several ordinary salaried presidents. The Captain's refusal of partnership was the only one which ever came within my experience. None of the other mechanics ever preferred salary to partnership, and they were wise. Nothing can compare with that form. From that time forward the union of the mechanical and business partners went steadily forward until no manager of a mill was without his interest in the business, as pertaining to the position, and no board of management or important committee was without a mechanical representative. Thereafter, mill and office conferred upon all important sales or contracts. The mechanic and the man of affairs were in constant consultation and fellow-partners,—one of the most profitable changes that we ever made.

There was another step taken in the same direction. Men having others under their charge were given an interest in the proceeds, or savings in cost, in their department. Where it was impossible to decide the limits of a department, the managers were rewarded by handsome bonuses beyond their salary, based upon the general profits of the year. Thus, as a rule, every man in authority became more than a mere wage-earner. He felt himself on the first step of the ladder which led to partnership sooner or later, and was worth any two mere employees paid only a daily or monthly wage and denied special recognition.

This plan of reward according to results, for heads of departments, has al-

ready become so general and is spreading so fast that we may be sure it has proved its efficiency. There are few large department stores or important houses in retail trade which have not been forced to adopt it.

This plan is probably bound to prevail to greater or less degree in manufacturing concerns, and the sooner the better, for the greater number of the workers capital can compensate, and in one sense reward, by sharing its gains, the more harmonious, and, therefore, more profitable for both, must the relation become.

I never see a fishing fleet set sail without pleasure, thinking this is based upon the form which is probably to prevail generally. Not a man in the boats is paid fixed wages. Each gets his share of the profits. That seems to me the ideal. It would be most interesting if we could compare the results of a fleet so manned and operated with one in which men were paid fixed wages; but I question whether such a fleet as the latter exists. From my experience, I should say a crew of employees *versus* a crew of partners would not be in the race.

The great secret of success in business of all kinds, and especially in manufacturing, where a small saving in each process means fortune, is a liberal division of profits among the men who help to make them, and the wider the distribution, the better. Unsuspected powers lie latent in willing men around us which need only appreciation and development to produce surprising results. Money rewards alone will not, however, insure these, for to the most sensitive and ambitious natures there must be the note of sympathy, appreciation, friendship. Genius is sensitive in all its forms, and it is unusual, not ordinary, ability that tells even in practical affairs. You must capture and keep the heart of the original and supremely able man before his brain can do its best. Indeed, this law has no limits. Even the mere labourer becomes more efficient as regard for his employer grows. Hand service or head service, it is heart service that counts.

One of the chief sources of whatever success may have attended the Carnegie Steel Company was undoubtedly its policy of making numerous partners from among the ablest of its men, and interesting so many others of ability in results. I strongly recommend this plan, believing that in these days of ever-increasing competition it will be the concerns which adopt this plan, other things being equal, which will survive and flourish.

Disputes of some kind between capital and labour are always in evidence; but it must never be forgotten that in the wide fields of domestic service and in that of the few employees with a working master which, combined, embrace by far the greater number of wage-earners, all is, upon the whole, satisfactory; there reigns peace, with the inevitable individual exceptions.

We see in this encouraging fact the potent and salutary influence of the personal element. The employer knows his men and the men know their employer; there is mutual respect, sympathy, kindly interest and good feeling, hence peace. In the extensive field of domestic service we best see how true it is, "Like master, like man; like mistress, like Nan." Here we have the relation of employer and employed in its closest form, and innumerable households testify to the harmonising effect of personal relations. The trusty servant becomes practically a member of the family, deeply attached to it, and the family reciprocates the feeling. Few householders are without old retainers and pensioners, and to the end of their days and even to that of the children of the household the relation remains unbroken. The friendship of the employers and their children for the old servants, and the affection of these for their masters and mistresses and their children, is one of the most delightful features of life.

What has produced this reciprocal affection? Not the mere payment of stipulated wages on the one part and the bare performance of stipulated duties on the other,—far from this. It is the something more done upon both sides,

and the knowledge each has had opportunity to gather of the other, their virtues, kindness,—in short, their characters. The strict terms of the contract are drowned in the deep well of mutual regard. Labour is never fully paid by money alone.

If the managing owners and officials of great corporations could only be known to their men, and, equally important, their men known to their employers, and the hearts of each exposed to the other, as well as their difficulties, we should have in that troublesome field such harmony as delights us in the domestic. It is mainly the ignorance of contending parties of each other's virtues that breeds quarrels everywhere throughout the world, between individuals, between corporations and their men,—and between nations. "We only hate those we do not know" is a sound maxim which we do well ever to bear in mind.

In the progress toward more harmonious conditions between employer and employed we see that the system of payment by fixed wage has been largely supplanted by payment according to value of service rendered by workmen in positions of authority over others, and by recognition not only in money, but in position, which often counts quite as much as coin, and not seldom much more with the ablest. There remains still receiving the fixed wage the great mass of ordinary workmen; but we see in the history of the relations of employer and employed that these have not failed to rise greatly also. The movement tending to improve the position of the worker has not passed over even the humblest, but has reached and benefited all.

Passing over the day when the employer of capital owned and managed his workmen as slaves, it is surprising to note that even as late as 1799 villeinage still lingered in Scotland. Miners and labourers were practically transferred with the mine when it was sold. Speaking recently to a most intelligent miner in Fife (and the Fife miners deserve their extraordinary reputation for intelligence, sobriety, and all the elements of good citizenship), I mentioned the fact that our forefathers were thus transferred, and contrasted the position now, when their committee was at that moment meeting the propertyowners in discussion as equal parties to a contract, both merchants,—one buying, the other selling, labour. To the inquiry what would be thought now if the employer desired to transfer the men with the mines, he replied:—"Aw, there would be twa at that bargain, I'm thinkin'." You have to be Scotch fully to appreciate the reply, for much lies in the accent, the twinkle of the eye, and significant nod.

The payment in merchandise in whole or part, and the obligation to perform certain duties to the employer, lingered after villeinage passed away; but to-day we have reached the stage of perfect equality between the two contracting parties. Each is free to demand terms or to terminate agreements. Labour is worthy of its hire, and is now paid this in coin, the law in many lands going so far as to make its claim a first charge upon the employer's property,—a great advance. But the irresistible pressure which has forced change after change in the relations of capital and labour still operates unchecked,—a sure indication that the final stage has not yet been reached.

We have evidence of this in another important advance, the Sliding Scale, which provides not a fixed wage, but in some degree a settlement by results. Increased demands brings higher prices and profits to the employer, which, in turn, brings higher returns to the workmen, so that as the employer's profits rise and fall, so do the workman's rewards. If I were asked what was the best service the Carnegie Steel Company was ever able to render the wage-earner, next to giving steady employment at wages equal to any, I should answer, by persuading them to adopt the sliding scale, with a minimum insuring living wages, at its works at Braddock fourteen years ago, which has given perfect satisfaction from that day to this, and is still in force, and has produced undisturbed harmony between capital and

labour. The sliding scale is a great advance over the fixed wage, not only by securing for the workman a prompter and more certain share of the profits, but also because it raises his status. He is something akin to a proprietor when he shares varying profits instead of having merely a fixed wage. He has risen in the scale, and is more of a man, and the more of a man, the better and more valuable the workman.

While the Carnegie Company interested its young men as partners and was always anxious to reward exceptional service, and carried the bonus system to an extent, perhaps, unknown in any similar organisation, the masses of the ordinary workmen could not be embraced under the limited partnership form, even if it had been thought desirable that their savings should be so invested. The objection to this from the point of view of the workman, which always arose in our minds and which we were never able to surmount, was the sad and instructive history of the largest manufacturing concerns, especially those of iron and steel.

It is an instructive fact that the majority of the largest manufacturing concerns in the United States have, at some period in their career, either been in the hands of receivers, been mortgaged, reorganised, or sold by the sheriff, to the great loss of their original owners. Indeed, those which have escaped financial trouble are the exceptions. More than once in the history of the Carnegie Company leading partners have been so doubtful of its future as to beg their more optimistic senior to buy large amounts of their interests at actual cost. The great Cambria Iron Company was twice in trouble, and once sold by the sheriff; Joliet Works were also so sold; the Bethlehem Company has twice been mortgaged; the 6 per cent. first mortgage bonds of the immense Chicago Works have sold for as low as 70 per cent., and its shares at less than one-half of their par value. The Troy Iron and Steel Company has lost heavily and undergone several reorganisations. It may be said that these disasters are of the distant past, but history has a way of repeating itself which we do well to remember. The Pennsylvania Steel Company has in recent years been in the receiver's hands. Its shares, in demand at $300 in 1881, sold in '93 as low as $20. There was no over-capitalisation in any of these companies. Only actual cash counted. Even to-day we hear of the Superior Iron Company being embarrassed,—after investing of cash capital $34,000,000 (£7,000,000). Its preferred shares, which recently sold for $80 per share, are to-day quoted on the Exchange at $15.50 (£3, 4s.). The common stock, last year at $36 (£7, 6s.) per share, sells to-day for $4 (16s.). It is just announced that our oldest and largest shipbuilding company must be reorganised, for which seven and a half million dollars (one and a half million sterling) are needed. Its shares, which have sold above $85, are now at $38. The vicissitudes of the leading iron and steel concerns of Tennessee and Colorado are still in evidence. Our friends in Canada have similar experiences. Shares of their large Dominion Iron Company, which sold at $60 last month, are quoted to-day at $25.

Our experience in America has not been peculiar. The year before last the iron and steel works of Germany were generally in depressed conditions, and their shares suffered heavily. I read a list of these losses at the time, which impressed me deeply. If I remember rightly, many declined one-half or more. Several important works were reported in financial trouble. Your own experience in Britain is similar. Not a few concerns, after vibrating between seasons of loss and gain, have, from time to time, had to be reorganised, entailing heavy losses upon shareholders. Uncertainty of results pertain not only to iron and steel, but to all forms of business operations, and are inherent in them.

Had the employees of leading American railway systems invested in their shares last year, they would already have lost nearly a quarter of their savings, Pennsylvania Railroad shares having fallen $38; New York Central, $40;

Chicago, Milwaukee & St. Paul, $41; Illinois Central, $42 per share. It will be said that these losses may be recovered. Quite true, but it is also true that they may be doubled. No man can tell.

It is this ever present danger of loss to the investing workman in all fields of investment which makes the government savings banks of Britain so great a boon, although only 2½ per cent. interest be allowed. The principal is absolutely safe, and this is the vital point without which little genuine good to the workers can result.

It is said that of every hundred individuals who embark in business, ninety-five fail. This seems incredible, but one has only to recall the number he has known, who have attempted and failed, to find that the percentage of failures is great indeed.

The path of iron and steel is strewn with financial loss in all countries, and all forms of business must encounter grave risks. Scarcely a week passes without news of embarrassment or failure in the industrial world. Thus it has ever been, and ever must be, while human nature remains unchanged.

Bearing all this in mind, the thought of asking the workingman to risk his precious savings in the manufacturing or any form of business was always discarded by us as too dangerous for him. He was advised to buy a home instead and save his rent. To facilitate this, money to build a home was lent to any employee who had the ground clear of debt. Their savings up to $2000 each were taken by the company and placed in a special trust fund, entirely separate from the business. Interest at 6 per cent. was allowed, to encourage the workman to save part of his earnings for old age. The funds received were lent upon mortgage on real property, generally to such workmen as wished to build homes. It was believed that this was the safest, and, therefore, the wisest, use of their savings which workmen could make.

The most convincing proof of the steady march of labour towards a recompense based more and more upon profits or dispensed in forms drawing capital and labour into the peaceful bonds of mutual obligation, is to be credited to the United States Steel Corporation, the largest of all industrial corporations. For this it deserves unstinted praise, as proving a genuine consideration for the interest of the workmen and sagacious thought for its own.

To this step earnest attention is invited, for it may well prove of surpassing importance and mark an epoch in the history of the relations of capital and labour. It may even be looked back to as having furnished the solid foundation for the solution of most of the troublesome questions between them.

It is in this form:—Twenty-five thousand of the $100 shares of preferred 7 per cent. stock were offered to its 168,000 employees at $82.50 per $100 (£16.12 per £20) share, in different amounts, according to their earnings. These were subscribed for twice over; nearly one-sixth of the men subscribed, —one-half being salaried men. Twenty thousand more shares of stock were afterwards provided, making 45,000 in all, worth about $4,500,000 (£900,000), monthly payments being received. Another distribution of shares is intended next year.

One valuable and praiseworthy feature is that for five years those holding their shares and still in the service are given a yearly bonus of $5 upon their shares, and during a second five-year term another bonus, amount not yet fixed, is promised. The third feature, equally praiseworthy, is the resolve to set apart yearly from earnings, should these exceed $80,000,000 (say, £16,000,000) 1 per cent. of the earnings, and for each $10,000,000 (£2,000,000) of earnings an additional one-fifth of one per cent., for a fund to be awarded to such of their officials and men as have, in the opinion of the finance committee, best deserved it, as a reward of merit and not *pro rata*. Such is the scope of this perhaps epoch-making advance, which is rendered possible by the joint-stock form with shares in small amounts, easily distributable among many thousands of workmen.

It will be noted that the investment is

at the risk of the men. This seems a feature which we may, however, expect the corporation to change as experience is gained, as the plan is most wisely stated to be subject to future changes. In most of the States of the Union labour's precious earnings, surely the most precious of all capital, are a first charge upon property, and this is, I believe, the only safe policy to follow. "Every workman a shareholder" would end most of the conflicts which sadden us, between capital and labour.

To effect this, every corporation could well afford to offer to distribute part of its shares among the saving workmen, and in case of disaster give preference to repayment of principal as a first charge. Any desired legislation, with proper safeguards, could be readily obtained, authorising corporations to make savings of employees, up to a certain sum for each, a preferred claim, ranking before mortgage or ordinary debts or the claims of shareholders akin to the mechanics' lien and the homestead exemption laws now in force in most if not all of the States. This seems due to the workingman, who, necessarily unacquainted with business, buys his shares upon trust, and becomes the beneficiary or the victim of his employers. He should be considered as an inexperienced youth in the affair; besides, he is asked to invest, not solely for his own advantage, but at least equally for that of his employer. His adviser is not a disinterested party, and, therefore, cannot be absolved from responsibility, which would, I am confident, lead the owners of the United States Steel Corporation to save their trusting workmen from loss through following their advice, this advice being intended to promote the mutual advantage of the company and the workers. The responsibility is not small, since the circular assures the workmen that they are offered "a safer and more profitable investment than the workman could possibly find for his savings elsewhere." How much better, therefore, that legal form should be given to the moral claim.

There is another consideration, the influence upon the prudent workman of distracting anxiety in regard to the absolute safety of what may be his sole provision for old age. He will see every morning the Stock Exchange quotations, for the American workman reads the papers. Only recently he would have seen the preferred stock of the United States Steel Corporation temporarily quoted lower than the price charged for it to him. This may mean little to the man of affairs familiar with the ups and downs of the mercurial Stock Exchange. But what must be the effect upon the uninformed workman? Of this I am well assured,—the workman whose thoughts are upon the speculative surprises of the Exchange will not prove desirable. Speculation is the parasite of business, feeding upon values, creating none, and is wholly incompatible with the satisfactory performance of other regular work requiring constant care and caution. The workman's investment should never be in jeopardy, for if his thoughts are upon the Stock Exchange they cannot be upon the machinery, and machinery, like art, is a jealous mistress, brooking no rival claimant to her absorbing demands. In the interest of the employer, therefore, as well as that of the workman, the savings of the latter should be secure,—here, as in other respects, their interest is mutual, and hence I believe the needed change will be made by the Steel Corporation in the near future. I cannot speak too highly of this experiment nor give the Steel Corporation too much credit for making it, since it is declared to be in the experimental stage, and subject to future improvement, as all new schemes should be.

Thus we see that the world moves on step by step toward better conditions. Just as the mechanical world has changed and improved, so the world of labour has advanced from the slavery of the labourer to the day of his absolute independence, and now to this day when he begins to take his proper place as the capitalist-partner of his employer. We may look forward with hope to the day when it shall be the rule that the workman is partner with capital, the man of affairs giving his business experience,

the workingman in the mill giving his mechanical skill, to the company, both owners in the shares and so far equally interested in the success of their joint efforts, each indispensable, without whose co-operation success were impossible. It is a splendid vista along which we are permitted to gaze.

Perhaps I may be considered much too sanguine in this forecast, which no doubt will take time to realise; but as the result of my experience I am convinced that the huge combination, and even the moderate corporation, has no chance in competition with the partnership which embraces the principal officials and has adopted the system of payment by bonus or reward throughout its works. The latter may be relied upon, as a rule, to earn handsome dividends in times of depression, during which the former, conducted upon the old plan, will incur actual loss and perhaps land in financial embarrassment.

In speaking of corporations we must not forget, however, that there are many which are corporations in name only, their management being the life work of their few owners. These rank with partnerships, having all the advantages of this form. The true corporation is, that whose shares are upon the Stock Exchange, and whose real owners change constantly and are often unknown even to the president and directors, while to the workmen they are mere abstractions. It is impossible to infuse through their ranks the sentiment of personal regard and loyalty in all its wonderful power. The step taken by the United States Steel Corporation is, therefore, no surprise to me, for I have long believed that such corporations would be compelled to adopt the best attainable substitutes for the personal factor of the older system, or suffer. In the sagacious policy of the United States Steel Corporation I see proof of that opinion; nor can I suggest a better form than that it has adopted, always provided the workingman shareholder be secured against loss.

In the percentage allotted by the plan to reward exceptional officials we have for the huge corporation perhaps the best substitute attainable for the magic of partnership, which nothing, however, can approach. The reward of departmental officials may readily be secured under this provision. In the bonus granted yearly upon shares held by employees we have proof of regard for them which cannot but tell, and the distribution of shares in the concern among them has an advantage which, so far, no partnership even has enjoyed. The latter will no doubt adopt the plan, or find some equivalent, for the workman owning shares in absolute security will prove much more valuable than he without such interest, and many incidental advantages will accrue to the company possessed of numerous shareholding employees who may some day see their representative welcomed to the board of directors. This would prove most conducive to harmony, knowledge of one another on the part of owners and workmen being the best preventive of dissatisfaction. If the investment of the workman's savings be made secure, the rapid extension of the plan seems certain, and can be hailed with unalloyed satisfaction; but in its present form it is obviously incapable of general application, since the officials of few corporations could or would incur the responsibility of inducing their workmen to invest in their shares as a security, and few corporations could or should inspire the needed confidence of labour that these are to enjoy an unbroken career of prosperity, for such has not been the history of manufacturing concerns generally, especially in our field, to which we may well apply the well-known lines of Hudibras,—

> "Ay me! what perils do environ
> The man that meddles with Cold Iron."

The idea of making of every workman a capitalist and of sharing large percentages of the profits among those rendering exceptional service will probably encounter the opposition of the extremists, on both sides, the violent revolutionist of capitalistic conditions, and the narrow, grasping employer whose creed is to purchase his labour as he does his materials, paying the price agreed upon and ending there. But this opposition

will, we believe, amount to little. It will even speak well for the new idea if scouted by the extremists and commended by the mass of men who are on neither dangerous edge, but in the middle, where usually lies wisdom.

Meanwhile, here is the germ of a promising plan offered as a solution for one of the pressing problems of our age, which may prove capable of development. That the problem will be solved, and that the two factors are some day to live in friendly co-operation, let no one doubt. Human society bears a charmed life. It is immortal, and was born with the inherent power or instinct, as a law of its being, to solve all problems finally in the best form, and among these none more surely than that vexed question of our day, the relations between these Siamese Twins, which must mutually prosper or mutually decay,—Employer and Employed,—Capital and Labour.

In connection with Mr. Carnegie's remarks special interest is attached to the profit-sharing plan of the United States Steel Corporation as outlined in a circular issued by that company at the beginning of this year, and addressed to its officers and employees. The plan is designed to make it the men's common interest to become permanent holders of the preferred stock of the corporation.

From the earnings of the corporation during the year 1902 there were to be set aside at least $2,000,000, and as much more as was necessary, for the purchase of at least 25,000 shares of the corporation's preferred stock for the purpose of making the following offer to all the employees of the Steel Corporation and of its subsidiary companies:—

At the present time there are in the service of the corporation, and of its subsidiary companies, about 168,000 employees, whom it was proposed to divide into six classes, as follows:—

Class A to include all those who receive salaries of $20,000 a year or over.

Class B to include all those who receive salaries of from $10,000 to $20,000 a year.

Class C to include all those who receive salaries of from $5000 to $10,000 a year.

Class D to include all those who receive salaries of from $2500 to $5000 a year.

Class E to include all those who receive salaries of from $800 to $2500 a year.

Class F to include all those who receive salaries of $800 a year or less.

During the month of January, 1903, the above-mentioned stock was offered to every man in the employ of the corporation, and all of its subsidiary companies, at the uniform price of $82.50 per share.

Every man can subscribe for as much stock as he chooses, not to exceed the sum represented by a certain percentage of his annual salary, as indicated in the following table:—

Any man who belongs to Class A, as indicated in the preceding classification, will be allowed to subscribe for an amount of stock represented by a sum not to exceed 5 per cent. of his annual salary.

Class B, 8 per cent.
Class C, 10 per cent.
Class D, 12 per cent.
Class E, 15 per cent.
Class F, 20 per cent.

If, on the basis of subscription, more than 25,000 shares shall be subscribed for, 25,000 shares will be awarded to the several subscribers in the order of the classes, beginning with the lowest, or Class F, the upper classes to receive stock only in case any shall remain untaken by the class below, and each class to receive ratably in the amount left for that class if there be not enough to satisfy the full subscription of that class; but each subscriber will be allotted at

least one full share, even though this might make it necessary for the finance committee to purchase more than 25,000 shares.

Payment of the subscriptions for the stock must be made in monthly instalments, to be deducted from the salary or wages of the subscriber, in such amounts as he may desire, not to exceed 25 per cent. of any one month's salary or wages.

A man may take as long as he chooses, not exceeding three years, to pay for his stock.

Dividends on the stock will go to the subscriber from the date on which he commences to make payments on account of his subscription.

Interest at 5 per cent. will be charged on deferred payments on the stock.

In case a man shall discontinue payments before his stock shall have been fully paid for, he can withdraw the money he has paid on account of principal, and may keep the difference between the 5 per cent. interest he has paid and the 7 per cent. dividend he has received on the stock; and thereupon his subscription and all interest on the stock to which the same relates shall cease..

As soon as the stock shall have been fully paid for, it will be issued in the name of the original subscriber and the certificate will be given to him, and he can then sell it any time he chooses. But as an inducement for him to keep it and to remain continuously in the employ of the corporation, or of one or another of the subsidiary companies, and to have the same interest in the business that a stockholder or working partner would have, the following offer is made to each man:—

If he will not sell or part with the stock, but will keep it, and in January of each year, for five years, commencing with January, 1904, will exhibit the certificate to the treasurer of his company, together with a letter from a proper official, to the effect that he has been continuously in the employ of the corporation, or of one or another of its subsidiary companies, during the preceding year, and has shown a proper interest in its welfare and progress, he will during each of such five years receive checks at the rate of $5 a share per year. For example:—If a man has bought one share of this stock in January, 1903, he will undertake to pay $82.50 for it. If after paying for it he keeps it for five years, he will in each year have received dividends at the rate of 7 per cent. on the par value of the stock, and also will have received each year an extra dividend, so to speak, of $5, this latter sum being paid him as special compensation for rendering continuous faithful service to the corporation or to one or another of its subsidiary companies, as shown by the exhibition of his certificate, together with a letter from a proper official, showing that he has worked to promote the best interests of the company in which he has thus become practically a partner.

If he shall remain continuously in the service of the corporation, or of one or another of its subsidiary companies for five years, at the end of the fifth year the corporation intends that he shall receive a still further dividend, which cannot now be ascertained or stated, but which will be derived from the following source:—

All who subscribed for stock in January, 1903, and commenced to pay for it, but who discontinue at any time during the five years, of course will not receive the $5 per share for such of the five years as remain after they discontinue. The corporation will, however, pay into a special fund each year the $5 payments that would have been made to such subscribers had they continued. This fund shall be credited with 5 per cent. annual interest, and at the end of five years' period the total amount thus accumulated will be divided into as many parts as shall be equal to the number of shares then remaining in the hands of men who shall have continued in such employ for the whole five years, and the corporation will then, by its own final determination, award to each man whom it shall find deserving thereof as many parts of such accumulated fund as shall be equal to the number of shares then held by him under this plan.

It is provided, however, that if a sub-

scriber shall have died or shall have become disabled while faithfully serving the corporation, or one or another of its subsidiary companies, during such five years' period, the money theretofore paid by him on account of the stock he was purchasing, or, if he has fully paid for it, the certificate of stock may be turned over by the corporation to his estate or to him, together with a sum equal to $5 per share for each of the five years not then expired.

If this plan shall be received favourably and shall meet with success, it is intended at the close of this year to make a similar offer, excepting, of course, that the price at which the stock then will be offered cannot be guaranteed now; it is, however, the intention to offer it at about the then market price, and in all other respects to make the terms of the offer similar to those now submitted.

The continuation of this policy would make it possible for a man to buy one or more shares of the stock each year under a contract with the corporation upon terms offering a safer and more profitable investment than he could possibly find for his savings anywhere else.

THE "KAISER WILHELM II."

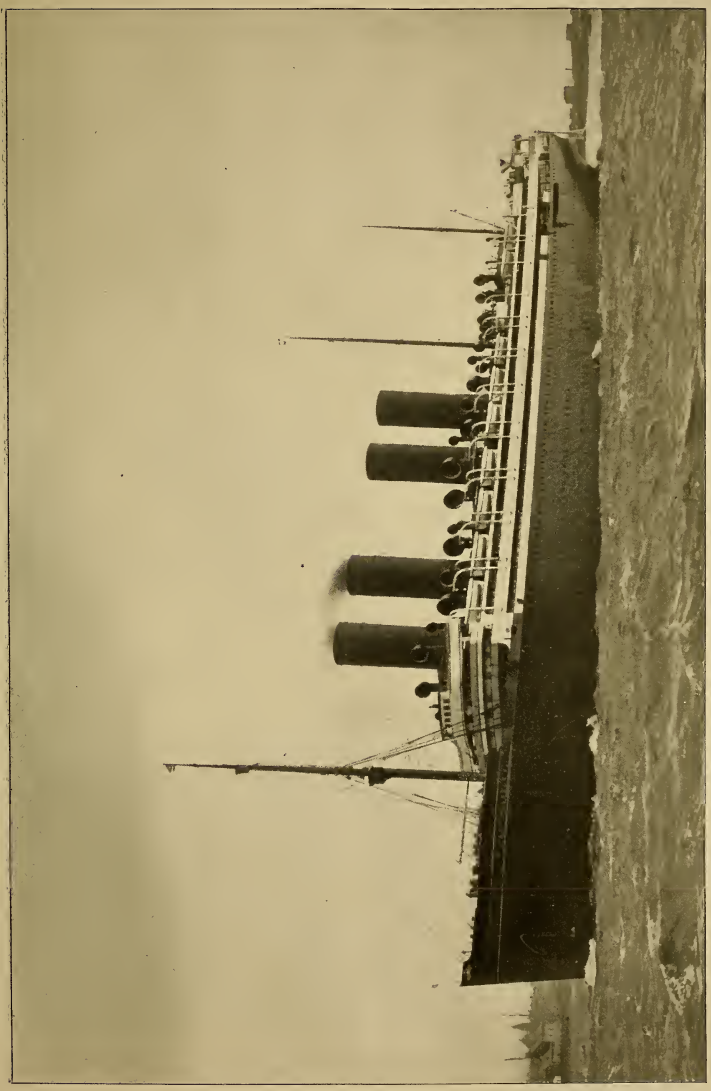
THE NEWEST AND LARGEST ATLANTIC LINER

By Gustav H. Schwab

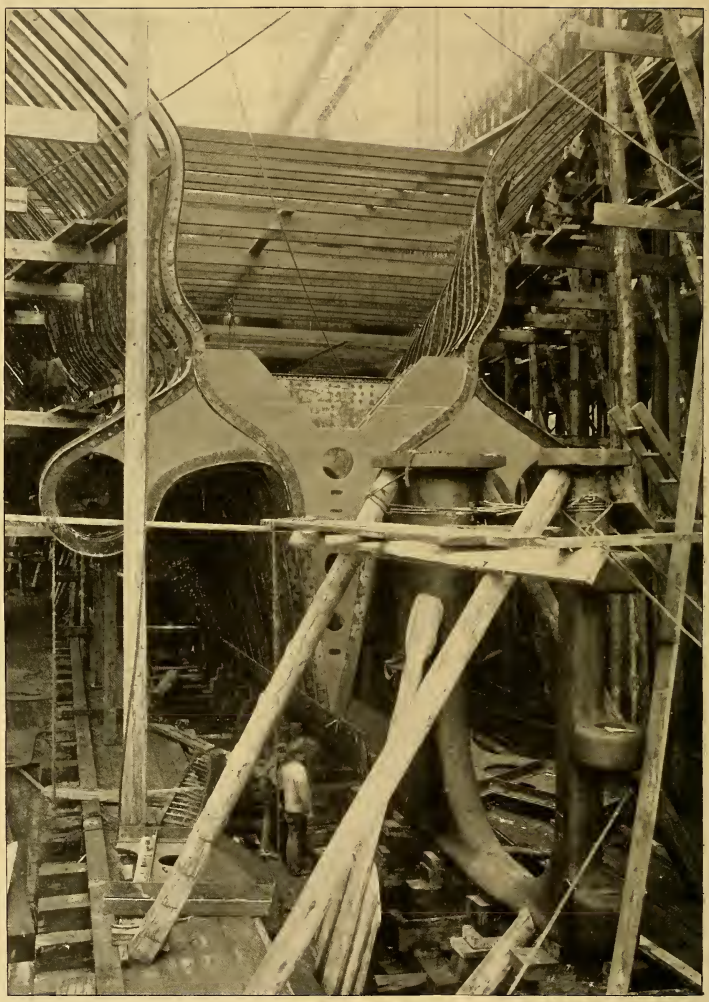
THE UPPER PROMENADE DECK

IN no branch of human activity has there been a more marked advance in the last quarter of a century than in ocean transportation. The progress made in the size, character, and speed of vessels, and in the provisions adopted for safety of life and property and for the comfort of passengers cannot be more vividly realised than by a comparison between the old timers and an express steamship of the present day. Thirty years ago the largest steamer that entered the port of New York on regular service across the Atlantic was of a gross register tonnage of 4670, her length was 440 feet, her beam 44 feet, and her horse-power 3000. The passenger accommodations on the steamers of that period were commensurate with the size and speed.

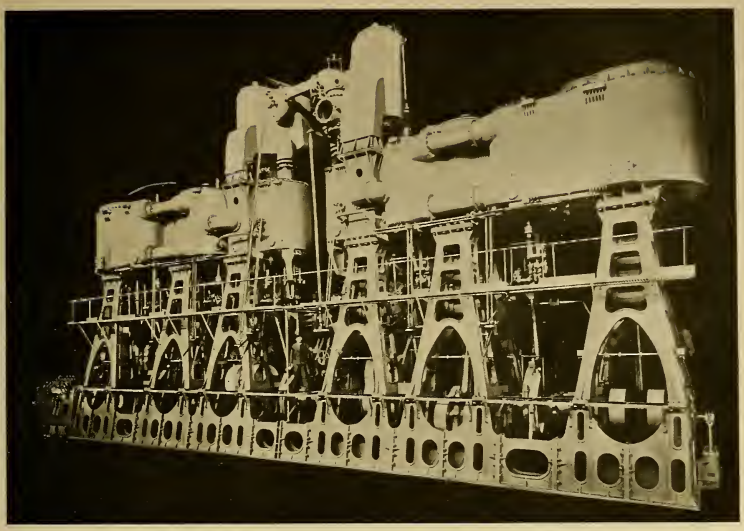
As against the modest dimensions of the largest steamship of those days we have to-day more than forty-five steamships of from 10,000 to 20,000 tons gross register employed in regular lines between the port of New York and ports of Great Britain and Continental Europe, not to mention the large fleet of vessels of a tonnage between 5000 and 10,000 tons gross register. The horse-power of these modern ships varies according to the service for which they were built.



THE NEW NORTH GERMAN LLOYD STEAMSHIP, "KAISER WILHELM, II." LENGTH, 706 FEET 6 INCHES; BEAM, 72 FEET 6 INCHES; DRAUGHT TO LOAD LINE, 29 FEET 6 INCHES; DISPLACEMENT, 26,500 TONS; INDICATED HORSE POWER, 40,000



AN EARLY CONSTRUCTION VIEW



ONE OF THE TWO SETS OF MAIN ENGINES, EACH SET DEVELOPING 20,000 H. P. AND CONSISTING OF TWO FOUR-CYLINDER, THREE-CRANK QUADRUPLE EXPANSION ENGINES

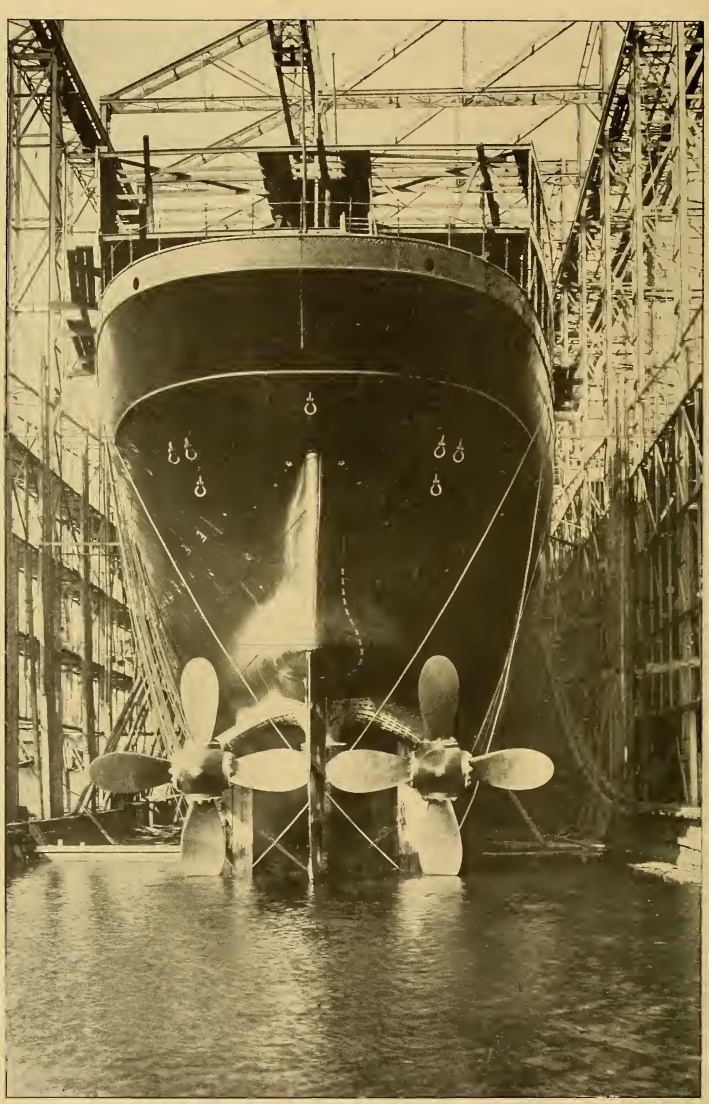
The large freight steamers have from 8000 to 13,000 horse-power, whereas the express steamships develop from 20,000 to 40,000 horse-power.

The latest addition to the large fleet of fast transatlantic liners is the steamship *Kaiser Wilhelm II.*, of the North German Lloyd, built by the Vulcan Shipbuilding Company, of Stettin, Germany, and launched on August 12, 1902, sixteen months after her keel was laid. At her launch the total weight of the hull was 11,200 tons. The dimensions of the new vessel are:—

Length over all	706 ft. 6 in.
Beam	72 "
Height from top line of keelson to moulding of promenade deck	52 " 6 "
Draught to load line	29 " 6 "
Displacement	26,500 tons.

In describing this latest triumph of the shipbuilder's art let us begin at the foundation, as it were, *i. e.*, at the double bottom, which constitutes the basis on which this colossal structure has been reared. The double bottom is nearly 7 feet high. The horizontal middle keel under the double bottom consists of a triple plating of a total thickness of 2¾ inches. The double bottom itself is divided into twenty-eight compartments and constitutes one of the most important factors in the steamer's safety, as it affords a most effective protection in case of damage to the bottom of the steamer.

The various compartments also are arranged to serve as tanks for the supply of fresh water for the boilers, as well as for drinking purposes, and for the storing of water ballast to compensate for the loss of weight caused by the consumption of coal and provisions during the voyage. The double bottom tanks of the ship hold 202 tons of water for the boilers, 866 tons of drinking water, and 2097 tons of water-ballast,—a total of 3165 tons of water, which exceeds the total displacement of a small cruiser. Besides the double bottom, the safety of the vessel is secured by seventeen watertight transverse bulkheads and one longitudinal bulkhead in the engine room, thus forming nineteen compartments which are so divided and calcu-



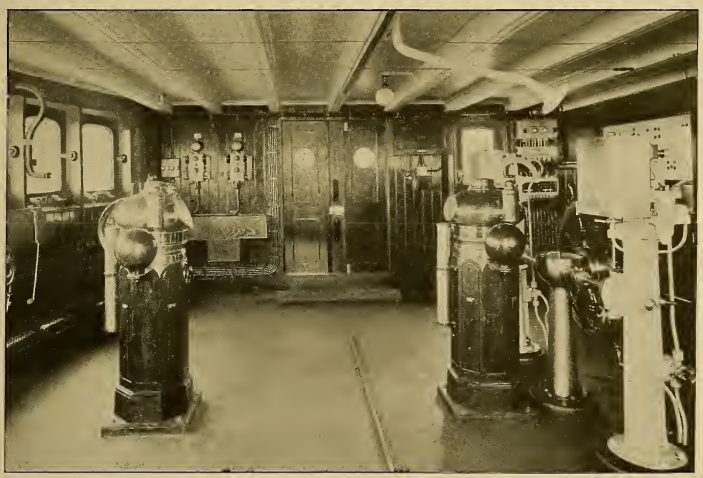
THE TWO BRONZE PROPELLERS ARE 22 FEET 10 INCHES IN DIAMETER. EACH HAS 20,000 HORSE-POWER BEHIND IT

lated as to insure the flotation of the ship even if two adjoining compartments should become filled with water.

The Doerr system of compartment doors has been introduced by which the doors in every compartment are placed under the control of the officers on the bridge, and are closed and opened from the bridge. By the movement of a lever there a bell is rung for a few seconds at every compartment door on the steamer as a warning signal, and then the doors descend and effectually close off every compartment. A large diagram of the steamer on the bridge on which the various compartments doors are indicated shows by small red electric lights what doors are open on the steamer and what doors are closed.

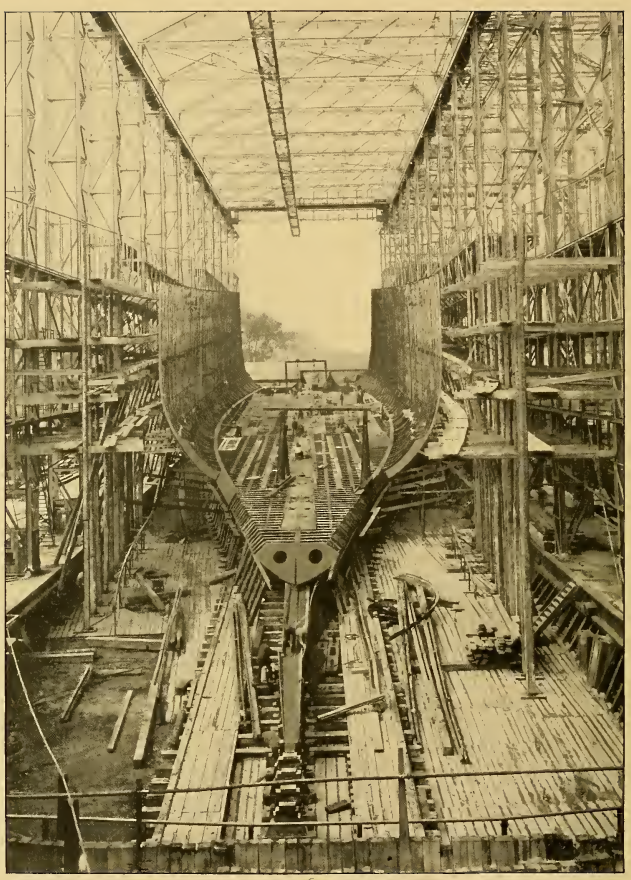
The vessel has five decks,—the spar deck, the upper deck, the main deck, the lower deck, and the orlop deck. Above the spar deck there is a second promenade deck and the awning or bridge deck. There are, thus, seven stories constituting the height of the vessel from the double bottom as the ground floor, the height of these stories ranging from 8 to 14 feet. The total height, measured from the top of the keelson to the roof of the smoking-room, is 72 feet 7 inches,—higher than the ordinary city house.

The steering apparatus is placed beneath the waterline, in view of the possible use of the steamer as an auxiliary cruiser in time of war. The engine turning the rudder is capable of moving it from "hard a-starboard" to "hard a-port" in a few seconds. On one of the upper decks a second reserve steering apparatus of half power has been installed, either apparatus being worked from the forward bridge and the after bridge by means of a telemotor, or by a hand-wheel through signals from the bridge; and in case of emergency or breakage the steamer can be steered by a tiller worked by means of tackles.



IN THE PILOT HOUSE

The two bronze propellers measure 22 feet and 10 inches in diameter, and each of them is driven by two four-cylinder, three-crank quadruple-expansion engines, each set of two engines developing 20,000 horse-power. The two engines on each shaft are placed tandem, and are separated by a transverse bulkhead between each engine in



THE DOUBLE-BOTTOM CONSTRUCTION IS HERE SHOWN

addition to the longitudinal bulkhead in the engine room; a separate watertight compartment is thus provided for each of the four engines. The crankshaft and the thrustshaft are made of nickel steel, while the screw shaft is of crucible steel, and the connecting shafting, of Siemens-Martin steel. The length of each set of two engines is 92 feet, and the height, 43 feet 4 inches. The high-pressure cylinder is placed above the first intermediate; next to the first intermediate comes the second intermediate, and then the low-pressure cylinder.

To provide the necessary steam for these four engines twelve double and seven single boilers are provided, working at a pressure of 213 pounds, and having a heating surface of 107,643 square feet. There are 124 furnaces, with a grate area of 3121 square feet. The bunkers contain space for 5700 tons of coal. The boiler rooms and coal bunkers have a total length of 295

feet, and a railroad track, 590 feet long, conveys the coal from one to the other. The fire-room force consists of 237 men. The nineteen boilers are connected with four large smokestacks, each 16 feet 5 inches in diameter and 131 feet in height above the keel. The daily coal consumption amounts to 625 tons.

The main and auxiliary engines taken together number 79, with 124 steam cylinders, and the condensers contain piping amounting to a length of about forty nautical miles.

Fire protection is insured by an extensive system of piping for both water and live steam, entering into every compartment. There is also a system of electric alarm bells which would automatically report a fire that might break out in any part of the ship.

Twenty-eight lifeboats are in readiness on the bridge deck of the steamer, and can be quickly and expeditiously launched, four boat hoists being provided for them. Seventeen powerful steam pumps are installed on the steamer, capable of discharging 9360 tons of water an hour in case water should enter any compartment.

Fresh air is provided by natural draught and also through artificial means by the aid of electricity. The *Kaiser Wilhelm II.* carries wireless telegraph equipment, and is capable of sending and receiving messages by this system.

The electric plant for the lighting of the steamer consists of 2700 incandescent lamps of 25 candle-power each. The smoking-room and the cafés are equipped with electric cigar lighters, and the first and second cabin staterooms with electric curling-iron heaters for the use of ladies. The whole steamer is fitted out with a telephone system and the necessary electric call bells.

Of kitchens there are four,—one for the first class, one for the second, one for the third, and one for the crew. The first class kitchen is 56 feet long and 30 feet wide. All the kitchens are fitted with the latest inventions, such as

A VIEW OF THE DRAWING ROOM

A BREAKFAST ROOM OF ONE OF THE TWO IMPERIAL SUITES

A BEDROOM OF ONE OF THE IMPERIAL SUITES

patent cooking ranges, patent saucepans, coffee mills worked by steam, etc. The pantries and sculleries are equally large. The first cabin pantry, for example, is 70 feet long and 18 feet wide, while the scullery for all the kitchens is 36 feet long and 17 feet wide. The pantries and adjacent entrances contain large cupboards for the silver and china, plate-warmers, electric machines for cleaning plates and knives, and everything else needed in these departments.

The large number of passengers carried on this steamer naturally calls for enormous space for storerooms, which aggregate 26,000 cubic feet, and hold the fresh meat, preserves, wines and spirits, dry and liquid provisions. There is a special post office aboard for the sorting of the Imperial German and United States mails, several post office officials of both countries being engaged in this work during the whole voyage.

Owing to the introduction of the Schlick system of balancing the engines, it is expected that the vibration will be reduced to a minimum and will not be felt to any appreciable extent in the passenger quarters of the ship. There are two hundred and ninety rooms for first cabin passengers and one hundred and seven for those of the second cabin. The most luxurious taste will find gratification in the two so-called "Imperial Suites," consisting of a bedroom, bathroom, parlour, and breakfast room, besides which the steamer is provided with eight "cabins de luxe," consisting of bedroom, bathroom, and sitting-room, and with twelve state cabins with private bathrooms.

THE LADIES' CAFE ON THE BRIDGE DECK

The dining-room for first cabin passengers is 108 feet long and 69 feet wide, and contains 554 seats; it has an area of 6560 square feet, and is decorated in white and blue. The woodwork is stained blue from the floor to the ceiling; all other parts are in pure white, the ceiling being decorated with oil paintings. From the centre of the dining-room ceiling rises the large skylight through three decks, measuring about 480 square feet, and decorated with paintings representing the seasons, hunting, fishing, agriculture, etc. The skylight is enclosed by colonnades,

THE SKYLIGHT WELL IN THE DINING ROOM

through which one can look down from the decks.

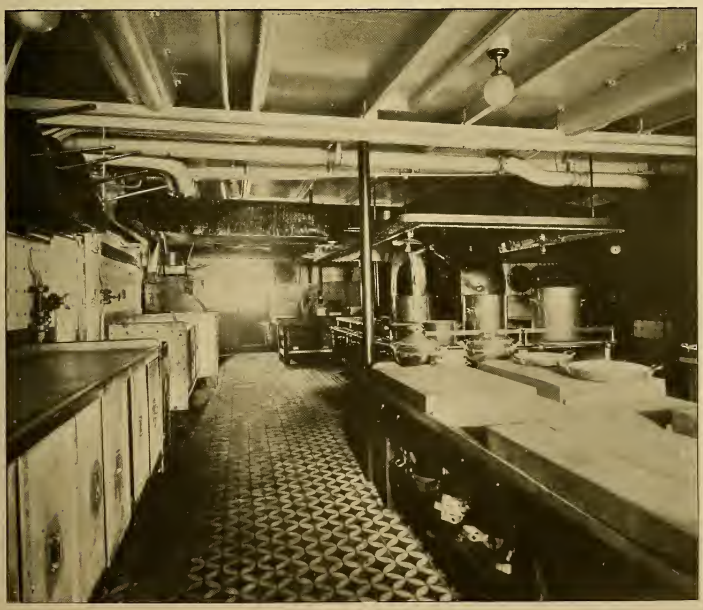
From the dining-room a staircase with richly carved banisters leads to a vestibule built around the skylight, and at one end of this vestibule the office of chief steward is situated, enclosed in a brass grating, which also contains the central station for the telephone system and a large safe for the passengers' valuables. A number of call boys are at the disposal of the passengers. The staterooms are generally arranged for two passengers, a number are single-berth rooms, and the large rooms, if desired, can be occupied by three or four passengers.

On the second deck above the dining-room the large staircase opens into a hall, at the entrance of which is a dining-room for children, decorated in red and white and with paintings representing scenes from fairy tales, making the apartment cheerful and bright. On the

following deck above is the drawing-room, containing a magnificent portrait of Emperor William II. The furniture of the room comprises a grand piano, comfortable lounges and tables and easy chairs. In the forward part of the deck-house on the promenade deck is a library and writing-room,—a bright and pleasant apartment, with panels decorated with fine lacquer-work representing flowers and birds in relief on a deep-red background. A large bookcase contains a fine assortment of general literature, and on one side, separated from the library by a glass partition, is a room in which a stenographer capable of taking English, German, and French dictation, and equipped with typewriting machine, is at the service of passengers.

Farther aft on this deck is the smoking-room, decorated in Renaissance style. The middle part of the room is capped by a large dome-like skylight, decorated with stained glass. The door at the end is executed in rich architectural design, flanked by columns surmounted by a strong arched cornice, on which rest two allegorical figures, representing Commerce and Shipping. Opposite, there is a magnificent fireplace with a marble mantelpiece and a copper hearth. The wainscoting of the smoking-room consists of mahogany with gold-bronze ornamentation, and is inlaid with leather in ornamental designs. The rounded corners of the room show allegorical reliefs, and the lounges along the walls of the room, as well as the arm-chairs and chairs, are covered with leather and arranged in groups. The ceiling is constructed in a design of light wood, from which incandescent lamps shed a pleasant light over the large apartment.

On the deck above,—the bridge deck,—two Vienna cafés have been installed, the larger one for smokers, the smaller



A KITCHEN VIEW

THE OPEN AIR CAFE ON THE BRIDGE DECK

forward one for ladies. Both are elegantly and cosily furnished, and, besides coffee, all sorts of dainties can there be had; in the larger one hot dishes are served if desired. In fine weather chairs and table will be placed outside the café, as in Paris and other large Continental cities, enabling passengers to enjoy their afternoon coffee in the open air with the view of the ocean before them. Aft of the larger café an open bower is built, where passengers may sit in the open air, sheltered from wind and rain. The bridge contains a large wheelhouse which shelters the man at the wheel and is equipped with telephones and speaking tubes leading to all parts of the vessel. The officers' quarters are situated immediately aft of the bridge on the bridge deck; the captain's room is immediately below the bridge. The engineers are berthed around the engine room.

The total complement of the ship's company consists of 600 persons, comfortable quarters for whom have been provided.

It is yet too early, at this time of writing, to warrant any specific claims for the speed of the new vessel; but it is not unlikely that she will equal, if not eclipse, the best existing record. Thus far her best day's run has averaged 23 knots an hour.

THE INDUSTRIAL REGENERATION OF INDIA

By John Wallace, C. E., Editor of The "Indian Textile Journal"

WHAT is to be done for a people numbering 287 millions whose country is rich in natural products, mineral, vegetable, and animal, and who are yet so lacking in resource that their once prosperous industries are failing, and a large proportion of them live constantly on the verge of starvation, having no reserves to fall back on in bad times? India has enormous resources in coal, iron, and other metals, gems, timber, fibre-yielding plants, merchantable seeds, and water-power; but although coal mining is in course of steady development, the valuable iron deposits are scarcely touched. The Kanagra tea planters have had to send to Japan for tea boxes, although living in a forest district with ample timber supplies and water-power; and in the Kulu valley not long since 16 per cent. of a contract lot of sleepers were rejected for bad cutting, because no one in the whole district seemed to understand the management of log saws. The native smith still forges locally-made iron on a stone anvil within eighty miles of Simla, and the greater part of the fibre and raw paper stuff rots annually in the jungles for lack of a system of collection, although both are in active demand, either for export or as supplies to local paper mills.

The population of India, according to recent census returns, is divided as follows:—

	Per Cent
Agriculturists	62
Industrial	16.4
Labourers	8.8
Government servants and professions	4.2
Domestic occupation	3.2
Commerce	3.1
Independent and unspecified	2.2

Taken together, the agricultural and artisan population of the Indian Empire numbers 222,967,970, thus representing 78.4 per cent. of the total, and for the present purpose these classes may be regarded as industrial, for they are all occupied in increasing the value, by manipulation, of the raw products of the country. The industrial progress of any country is so closely dependent on the technical ability of its working classes that an examination of their past and present condition may lead to some useful conclusions regarding their fortune. The word technical is here employed to indicate that portion of knowledge which can be acquired only by the hand and eye, but which cannot be committed to paper. It is thus distinguished from scientific knowledge.

The industrial population of India consists of men who have little or no literary knowledge; their habits are guided by custom and tradition, and they are singularly deficient in the inventive faculty which a scientific education does not develop. Even at the present time almost all the inventions patented by natives of India are the work of men who have not been to a college. Indians are, as a rule, willing and industrious workers; but they have no recognised standards of accuracy and no exact standards of measurement. Their *gudj*, or 2 feet, is the girth of the head vertically, and the distance from the elbow to the tips of the extended fingers is held to be 18 inches. By this measure cloth is sold in villages. The end joint of the thumb is an *angle*, or inch.

The Indian idea of time is as vague as that of measure, so that habits of

A MORTAR MILL OPERATED BY WATER BUFFALOES

punctuality are very slowly acquired. Endowed with an excellent memory, the workman lacks mental concentration, his mind is too frequently occupied with ideas foreign to the work in hand, and, if drawn into conversation regarding his work, his replies indicate a disposition to evade a direct answer or else an attempt to change the subject. Even in crossing a busy road he will look in any other direction than that he is following. This habit may be regarded as a national characteristic.

The Indian workman, when put in charge of boys or men, will communicate none of what he considers his special knowledge, although he may be engaged as a teacher; his lack of originality makes him very jealous of what he may regard as a trade secret, although much of this knowledge would be considered as common property in other countries. His strong point is his ability to live and work hard on twopence a day; and this, after he has received such instruction as he is capable of assimilating, will give him a very important place among the world's industrial forces.

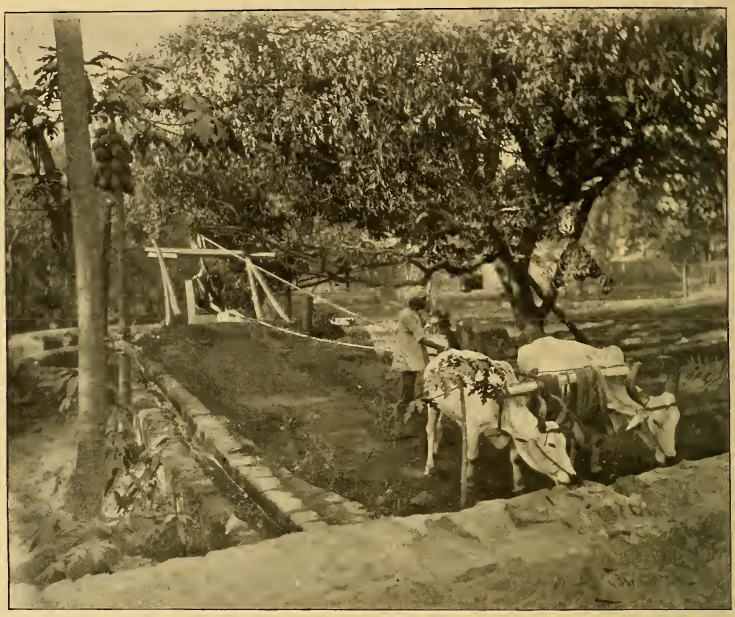
There is no law to enforce attendance at school. Children are sent to school at the will of their parents, and the duration of school attendance depends entirely on the appreciation of the parents, who are practically the final judges of the value of the instruction given to their children. In a country where early marriage is still a religious necessity, apart from all economical considerations, the education of children is reckoned by its money-earning value. It is, therefore, not surprising that the agriculturist and the artisan should set small store by the learning that adds nothing to the abilities of the workman. The prospective artificer who, when he grows up, will grudge the price of a 2-foot rule, is never taught that a quarter-anna coin is a standard inch, and that a dozen fairly new ones, placed in a row, will measure a foot. It is the habit of the Indian workman, when given an article to copy, always to do work that is inferior to the original,—a copy superior to the original is quite unknown.

In decorative art the habit of copying, and working from memory has so completely superseded the study of natural forms that what is generally known as Indian art consists largely of floral and animal monstrosities false in every single detail; but so ingrained has the taste for this style of work become that the people do not appreciate correct representations.

The conservatism of the Indian, for which the caste system seems to be mainly responsible, has so wedded him to stereotyped modes of industrial procedure that foreigners now outbid the native tanner for the skins he used to convert into leather. Shiploads of Indian iron ore are now exported to make English steel; oil seeds, gums, and paint pigments are exported, to return as paints and varnish, and tanning materials go out to aid the foreign tanners who send back the finished goods. At the same time manufactured goods of all kinds are poured into India from the highly organised manufactories of Europe and America, making it daily more evident that cheap labour alone is no match for the highly paid and highly trained skill of the foreigner; and as a protective fiscal system like that of America seems to be impossible in India, the only course that is open to save the economic situation is to raise the standard of efficiency of the working classes.

Industrial ineptitude has not always been characteristic of the Indian people, for there are many evidences to be found in the country of a period of intellectual activity so remote that it has left no historical trace, and yet so vigorous as to have bequeathed to succeeding generations all the best mechanical inventions they possess. First in importance is the *mot*, an appliance for raising water from wells for irrigation. Such an appliance must be simple, efficient, cheap, and easily maintained with material of local origin. The *mot* meets all these requirements. It is a bag of tanned leather shaped like a common teapot without lid or handle, having a stiff ring of wood or metal in the mouth, from which it is suspended by a fibre rope passing over a pulley in the well head.

A second rope is attached to the



THE INDIAN "MOT" FOR RAISING WATER,—A LEATHER BAG HAULED UP BY BULLOCKS

leathern spout and passes over another pulley level with the coping of the well. Both ropes are attached to the yoke of a pair of bullocks which walk down a ramp constructed against the well head, so that their weight, as well as their muscular force, is employed in raising the water. When the bag has reached the level of discharge, the leathern spout has been drawn over the lower pulley and it discharges into a channel prepared for the purpose. The whole apparatus is extremely light, as compared with its load, and when the bag is proportioned to the strength of the animals a very high degree of efficiency is obtained. But it is rarely seen in perfect order. The bag leaks, the pulleys run dry, or the load and lift are not adjusted to the capacity of animals.

The Indian emery wheel is a disk of wood mounted on a wooden axle with metal peg centres. The disk is turned true on the edge and dressed with a mixture of shellac and pounded garnets, which are very common in the country. It is operated by a labourer, who, with a strap about the axle, gives it a reciprocating movement, while the grinder holds his work against the periphery. This appliance continues, without improvement, in its crude original shape, requiring two men to work it, although the scissors grinder perambulates the larger towns with his foot-driven wheel. But he is a Persian or an Afghan, and no fit model for Hindus, who know nothing of the revolution that has been wrought in western workshops by the development of their parent appliance.

The turbine water mill is a machine of unknown antiquity. It is used, with little variation in structure, throughout Asia Minor, the Caucasus, Persia, Afghanistan, and India. It consists of a short, vertical shaft having a disk fitted with paddles at its lower end and a small pair of millstones at the upper end.

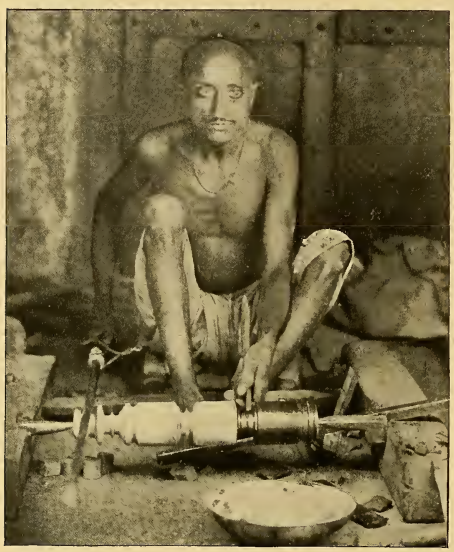
The shaft passes through the floor of a cabin built over the mill race, and the water supply flows down an open wooden spout and strikes the blades of the turbine. The T-piece driving the upper stone is generally the only piece of metal in the structure. The cost of the mill and turbine is about ten rupees, and although so extensively used for grinding grain, no one has attempted to turn a grindstone by the same means to sharpen tools.

The Indian lathe is probably the most ancient of all machine tools; it is too old to be attributed to any one country, but it retained its original form without any attempt to give it a continuous rotation until the advent of Europeans. This was not for lack of a model, for the Indian spinning wheel, a very ancient machine, has exactly the movement required to make the first step in advance,—a separate driving wheel and a cord. The Indian turner shows much ingenuity in turning hollow vessels between his fixed centres, and his method of enamelling turned work would be hard to beat. A small charcoal fire is pushed below the rotating piece until it is warm enough to melt a piece of coloured shellac, like sealing wax, held against it. When enough of lac is applied, it is smoothed and spread while cooling with a piece of dried water rush, which does not seem to adhere to the lac. In this way a surface is obtained that looks well after forty years.

The rope yarn spinner is a very simple form of machine that converts a reciprocating into a rotary movement in one direction. The movement is intermittent, but it does not reverse like the lathe, and as it dispenses with a driving wheel, it is exceedingly cheap. A cord that passes round two or three rollers is pulled at opposite ends, the ends alternately gripping and slipping. Judging from the conservative spirit that rules the industries of India, one may suppose that all these appliances were invented before the institution of caste began to exercise its repressive influence. As a social institution, caste has many advantages,—it preserves family unity,

AN INDIAN EMERY WHEEL

provides relief for the poor and sick, and so long as India was cut off from close intercourse with Europe it seemed to meet the industrial needs of the country. But once thrown open to intimate commercial relations with more advanced countries, caste restrictions became a drag on industrial progress for reasons which may be easily explained.



A HINDU WOOD-TURNER. THE INDIAN LATHE IS ONE OF THE MOST ANCIENT OF ALL MACHINE TOOLS

As hereditary occupations do not insure a transmission of the necessary aptitude or talent, all trades must count among their numbers workmen who are either unskillful or unable to impart technical knowledge; many of them are weak in both respects. When such men are obliged not only to follow their father's trade, but also to teach it to their sons, there is more than a risk of deterioration in the craft, which, under such circumstances, must be carried on in families and not in factories. Again, every improvement in processes of work is jealously guarded as a secret by the inventor, even at times from his own relations, so that the spread of technical knowledge is retarded instead of being aided by the caste system.

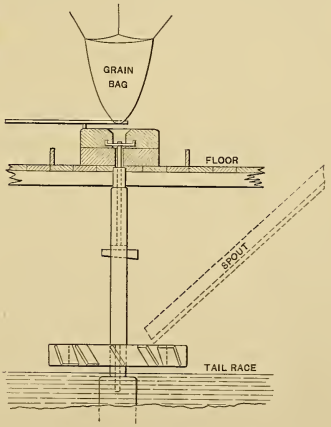
Various educational influences have been at work in India to improve the condition of the people, the Educational Department of the Government being the most prominent; but the staple education in primary schools has been of a literary and not of a technical character, and it bore so small a relation to the ultimate career of the boys that very little of it remained after a few years. This was very clearly stated by Mr. I. C. Nesfield, Director of Public Instruction in the North-West Provinces of Oudh, who published, in the Calcutta *Review* in 1887, the result of an examination he made into the effect of primary school training. Out of 3024 scholars who had left school he found 2165 with whom he could communicate, and these he invited to be examined in the subjects in which they had received instruction. Out of these, 1037 accepted his invitation, with the result that 16 per cent. passed in one or more of the simple subjects (reading, writing, and arithmetic) and in one or other of the three more difficult grades, while the remaining 84 per cent. failed to pass in any one subject whatever. The instruction imparted to them appears to have been of no use to them in their daily work, as they had neither reading, writing, nor calculating to do, and they forgot their schooling as people forget the things they do not practice. The short receptive period in the lives of the youths examined had been sacrificed to a system borrowed from another and totally different country. Mr. Nesfield found that primary education made the children of cultivators less contented with their lot; they went back to the plough with the greatest reluctance, their ambition, if they had done well at school, being to

get clerical employment. The agricultural labourer in India has many points in common with the Egyptian *fellah*, as described by Professor Flinders Petrie. The latter, if forced to learn reading and writing, is liable to become stupid, although he can readily assimilate and utilise information that refers to his daily work. Professor Petrie was of the opinion that people of that kind can take in only a limited amount of new knowledge per generation. This being accepted, it is evident that the class of new knowledge which is likely to be best for them is that which refers most directly to their daily work, and thus we arrive at the kind of instruction that is likely to be most acceptable and most profitable. Those parts of natural history that deal with the animals he owns, the vermin he kills, the trees and plants he grows or uses, the choice and germination of seeds, the protection of sources of drinking water, the properties of materials,—these are the subjects that concern an agriculturist, and they should be imparted in familiar language and with the aid of a blackboard by a man of the people, specially trained for the purpose, but not overloaded with surplus knowledge.

For ages the *ryot* has believed that all snakes are equally poisonous, and many men are said to die of fright after the bite of a harmless snake. How easy it would be to teach, with the aid of coloured diagrams, that there are only six deadly snakes, and to familiarise children with their appearance. And as reading and writing are so readily forgotten, simple freehand drawing and elementary arithmetic would be found more useful substitutes, as the need for them would occur more frequently in the after-life of the school boy, besides assisting materially in his class training.

The Indian craftsman is very little understood except by the persons who employ him. Visitors to art or industrial museums, or to exhibitions such as that held in connection with the National Indian Congress at Ahmedabad in December, 1902, carry away a very false idea of the state of the industrial arts. They see the best work of the best craftsmen in various parts of the country, but this best work bears a very small proportion to the total. Although the average work is very imperfect when judged by the standard of the imported goods that are displacing it, there is ample evidence of the existence of good native workmen who need only to be multiplied in order to increase the industrial power of India. The ability of the woodworker is generally taken as a measure of the craft of a country; he was, therefore, the subject of discussion in Bombay by a committee appointed recently by the government to enquire into the state of technical instruction throughout India.

The opinion of the leading architects, engineers and cabinetmakers was unanimous regarding the ignorance and unreliability of every class of wood-



INDIAN GRAIN MILL AND WATER TURBINE. THIS IS A MACHINE OF UNKNOWN ANTIQUITY

worker, and one witness, speaking of a batch of youths who had finished their course in the largest school of cabinet work in the presidency, said that the young men had not been taught to think, and that they could not undertake any work without the most elaborate instructions as to how to set about it. No

THE INDIAN ROPE YARN SPINNER CONVERTS A RECIPROCATING INTO A ROTARY MOVEMENT IN ONE DIRECTION

technical institution in India has so far made a reputation for its pupils, and employers are bitter in their complaints that the youths from technical schools do not possess the kind of knowledge they are willing to pay for. They also complain that they have never been consulted regarding the course of studies laid out for the boys they are going to employ. Parents and pupils alike are only now beginning to realise that engineering colleges do not turn out engineers and managers of works, but only students who have their experience yet to gain before they can be entrusted with positions of responsibility.

One serious defect in technical instruction as applied to prospective workmen in India is the utter absence of trained instructors. There is no normal training school for instructors in craft in India. A good workman is generally placed in charge of a class and requested to teach; but as the faculty of imparting knowledge is one of the rarest of gifts, the man may, and does, carry on his work for years without ever suspecting that he is not teaching at all. This anomaly can be explained only by the fact that the directors of public instruction in India are university men who have neither learned nor practiced a handicraft. A separate department has recently been proposed to take charge of technical education in India.

For many years past the real technical schools have been the workshops attached to railways, docks, arsenals, and other factories under European control, where Indian workmen have learned to turn out excellent work and to earn pay far in excess of any past experience. In addition, they acquire habits of order and discipline which the school had failed completely even to initiate. But all the workshops could train only a very small fraction of the industrial population, and further, the men, having become specialised, remain with their employers, and do not carry the effect of their training throughout the land. The new methods of work have so few points of

contact with the indigenous methods that they can be followed only in modern workshops. The great question of technical education remains, therefore, almost untouched; but experience has been accumulating which, if properly considered, seems to offer a practical and practicable solution.

More than forty years of work in science colleges and technical schools have failed to effect a perceptible change among the industrial classes. The pupils from industrial schools revert promptly to indigenous methods of work on going out to earn their living, and if they have been trained to use the labour-saving tools of precision of England and America, they are less efficient when deprived of them than if they had been trained with the more primitive tools of the craft. Much has been expected of the students of science and technical colleges who recruit the Public Works Department; but whatever their scientific attainments may be, the very limited time they pass in the workshop gives them a mere smattering of craft,—enough, perhaps, to materially assist the assimilation of the lectures they attend, but totally insufficient to enable them to control workmen, who are quick to take advantage of the very evident practical ignorance of their supervisors. The situation is the more remarkable in India on account of the scarcity of capable foremen.

Two very important examples of technical education on a non-literate basis are at present in successful operation in India,—the modern textile industry and that of aluminium. The first cotton mill was built by an American. The enterprise was soon after taken up by energetic native merchants, who, having no industrial education, had to hire their technical assistants from abroad. The operatives were, and continue to be, drawn from the ranks of agricultural labourers, who in a short time can qualify to receive more than twice their original earnings. They do not abandon their hold on the land they previously tilled, and they usually return to their village and to agriculture at or near the age of forty. No protective duties foster the cotton and jute industries in India; they were a purely commercial undertaking, carried out by merchants and unsupported by schools. Large profits for many years rewarded the enterprise of the millowners, and at present the number of mills is approximately as follows:—Cotton, 184; jute, 30; woollen, 3; while the ginning factories number 370, and the baling presses 305. In these various factories the instruction imparted to the operatives refers directly to the work to be done, and does not touch extraneous subjects.

The second example comes from the Madras School of Arts, and belongs to the Educational Department. It was initiated and carried through by Mr. A. Chatterton, C. E., the principal, who, in the space of three years, introduced the use of aluminium to one of the oldest and most conservative of castes in India,—that of the coppersmiths, and although the metal required new methods of treatment, the change was effected with such careful regard to the intelligence and habits of work of the men that the new metal has "taken on," and the business that grew up at the School of Arts assumed considerable dimensions. One of the best customers was the Indian army, which promptly recognised the saving in weight that followed the exchange of brass and copper cooking and other vessels for those of aluminium.

Mr. Chatterton trained as many men and boys as the workshop could accommodate, and by degrees a demand arose among the Madras coppersmiths for supplies of sheet aluminium, which were furnished by the school. Towards the end of the fourth year the native artificers began to complain of the competition of the School of Arts, which was a sign that Mr. Chatterton's enterprise approached completion. No standard of literary education was required of the operatives employed. The instruction was purely technical, and the experiment, which has no precedent in the Educational Department, should serve to convince that body that technical education on a non-literate basis is the form of instruction best suited to the im-

mediate needs of the majority of the 222 millions representing the industrial part of India's people. The aluminium business of this School of Arts has recently been transferred to the Indian Aluminium Company.

As the Indian parent is not obliged to send his son to school, it is evident that the course of training offered must present some very palpable advantage to retain the boys for a sufficient time to show useful results, so that whatever the training may ultimately become, the beginning must be simple and eminently practical.

Professor John Perry, speaking of the education of engineering students at the last meeting of the British Association, went very near the mark when he said:—

"Whether the pupil comes from a bad or a good school, whether he is an old or young boy or man, approach his intelligence through the knowledge and experience he already possesses. The principle involves that we shall compel the teacher to take the pupil's point of view rather than the pupil the teacher's; let lectures be rather to instruct the student how to teach himself than to teach him; show the student how to learn through experiment and how to use books so that when he enters any works he may go with an observing eye, an understanding brain, and a fairly skillful hand. He may thus go on teaching himself through the medium of his daily work."

Speaking of the Finsbury College, where he was trained, Prof. Perry said:—"There were workshops in wood and iron, not to teach trades, but rather to teach boys the properties of materials." The art of thinking rationally and methodically about work seems to have been overlooked in technical and industrial schools in India, but this need be no matter for surprise, as the instructors have not been trained in the art of teaching. Men have been put in charge of classes whose sole merit was the art of acquiring technical knowledge, but who had no idea of the art of imparting it. Normal schools for instructors in craft do not yet exist in India. How much

AN INDIAN HAND LOOM

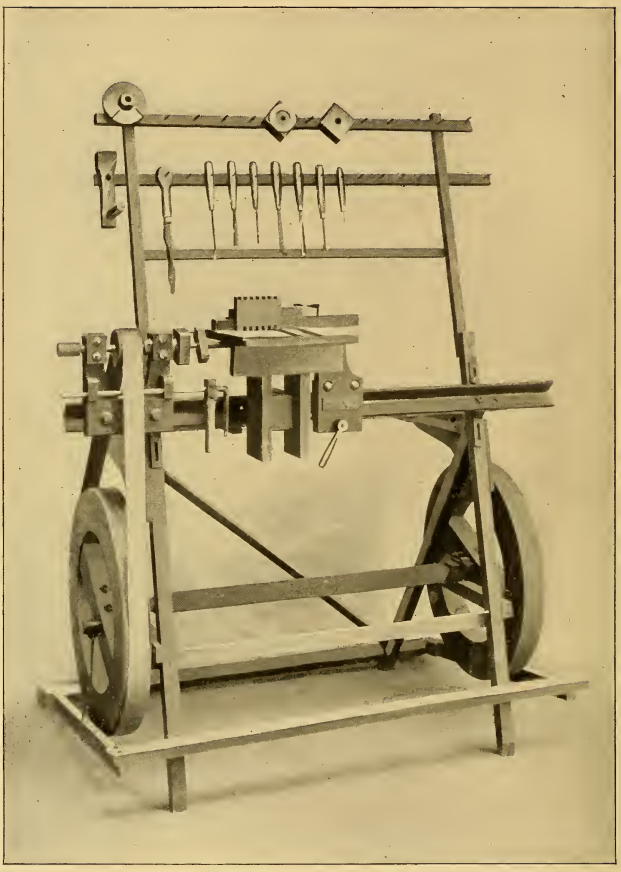
such schools are needed may be inferred from the fact that, as a rule, the master builder, cabinet-maker, carpenter, leather worker, plumber, painter, tailor or decorator is not a craftsman; he knows current prices, but he is no expert in workmanship, and his son will, if he follows his father's business, learn no more than can be acquired by looking on and keeping accounts.

The most cursory review of the industrial history of any country will show that progress has been from the ranks upward and not from the college downward. Even Japan, whose remarkable progress in recent times is so often quoted, forms no exception to the general rule that technical efficiency precedes the need for literary instruction. It is only within the last thirty-five years, according to the Japanese consul-general at Bombay, that the Japanese craftman took to reading and writing, but for centuries his workmanship was famous for its excellence. India can, therefore, form no exception to the general rule, and seeing the very backward state of her industries, and of her artisan population, the subject of industrial reform acquires an urgency that is second to none, for on the development of her natural resources depends her financial prosperity.

AN INDIAN TRAINING SCHOOL DRILL PRESS

The problem before us is the industrial regeneration of the labouring population of India in the shortest time, in the most effective manner, and at the lowest cost. The latter factor is of great importance, as the undertaking is so vast that unless the system is economical there will not be funds available for the purpose. The urgency of the work finds its justification in the admitted poverty of the people and the enormous undeveloped resources of the country,—and the present situation. Time is money here, as elsewhere. The two examples just described of purely technical instruction furnish ample proof of the suitability of this class of education to the immediate needs of the people, and as it would be impossible to enter into the details of every industry on the present occasion, it will suffice to deal with carpentry as a typical industry, because in India it includes all workers in wood.

The chief faults of the Indian carpenter are his neglect of accurate measurement, his carelessness with regard to the efficiency of his tools, and his lack of perception of the value of time as a factor in the execution of work; he has also to be taught to occupy his mind



A LATHE FOR INDIAN TRAINING SCHOOL USE, WITH DOVE-TAILING ATTACHMENT

with the work in hand, and as much as possible to exclude other subjects. The following is, generally speaking, an outline of the work of the technical instructor who has yet to be trained before the real industrial reform can begin. The instructor should be a man of the craft who, before receiving his special course of training, should have shown some special aptitude in his calling, and the course of instruction should be divided between manual exercises and demonstrations at the blackboard, each student instructor taking his turn and demonstrating before the others some familiar operation, and the reasons attached to it.

For example, the making of a jack plane involves the choice of the wood, considerations as to size. the angle of the blade, and its cutting edge, the wedge and its holding power, the

handle, and finally the operation of planing. All these operations are capable of very simple explanation, and this exercise provokes an emulation among students while exercising their reasoning powers. No Indian workman buys a plane; he buys the blade and makes the rest; but he rarely makes it well. He buys a saw blade and makes the handle, and, generally speaking, he spends the smallest possible sum on his outfit, in spite of the extra labour the economy involves. He must, therefore, be taught to make as many labour-saving tools as possible, and to make them well. He has to be taught the use and repair of a grindstone, and how to mount it in wood without metal fittings. The hard, tough woods so common in India make this an easy matter. The Indian has yet to be taught that grinding and whetting are two distinct operations, the first, removing 99.9 per cent. of the metal, and the second, producing the cutting edge in a few strokes. His saw is in such bad order that he cuts tenons, as a rule, with a mallet and chisel, and his ignorance of gauges renders him unable to make even twenty articles exactly alike. He rarely knows what size of nail or screw to use on a given job; his screw is always too small.

The pay of the instructor in craft should not exceed that of a workman of the best class in his trade, and his mind should not be loaded with too much knowledge. But he ought to know very thoroughly what he has to teach. His equipment in tools should be a reasonable advance on the ordinary kit of the carpenter, but there should be none of the very attractive labour-saving tools that are now so much in vogue in Europe, and which at present are quite beyond the means of the Indian workman. The construction and uses of the plumb level should be taught instead of that of the spirit level, and the instructor should learn something of the qualities of the steel used principally by the Indian artificer,—old files, spring plates of railway and other vehicles, mill spindles, from which the most of their tools are made by the village smith. The school should have some good steel tools for the purpose of comparison, but the pupil should still be taught how to make the best of the second-hand material, as it will be all he will get in most places when he goes out to work.

A normal training class for instructors in carpentry is about to be opened in Bombay where some of the above ideas will be carried out. Part of the equipment will consist of foot-lathes and drilling machines designed expressly for Indian workmen. The bed of the lathes is an angle bar, the spindle, centres, and bolts are of metal, and the rest is of teak or hardwood. A 6-inch circular saw and adjustable table are also provided, and two additional simple devices for screw cutting and making dovetailed boxes. The dovetail cutter will operate on eight thicknesses at once. The drilling machine has quick and slow-speed tools, and makes holes up to 1½ inch. The table is adjustable, and a stop motion enables any number of holes to be drilled to a fixed depth. All repairs required by these tools may be carried out by a carpenter. The building of these and similar tools should be part of the training of the instructors, who would thus furnish the outfit for village schools at the least possible cost. The fact that machines of precision may be made of wood is very little known in India; it should be carefully inculcated at schools to enable the workman to obtain the greatest return for his labour.

All the principal industries require a similar overhauling after a thorough study of their peculiarities. They need not all be attacked at once, but may be taken in the order of their importance, and as they may all be said to be more or less in competition with similar, but more highly organised, industries in other countries, their weakest points will demand the first attention. To measure correctly, to use sharp tools, and to cut to the mark are axioms that lie at the foundation of all good workmanship, and they indicate the chief defects of the Indian artificer. But in all schemes of industrial reform the greatest danger lies in doing too much. The statement of Professor Flinders Petrie is true in two senses,—the limits of true

THE WROUGHT-IRON PILLAR OF DELHI. THE PILLAR IS 16 INCHES IN DIAMETER AND EXTENDS 22 FEET ABOVE THE GROUND. ITS TOTAL LENGTH IS VARIOUSLY CLAIMED TO BE FROM 48 TO 60 FEET, AND ITS WEIGHT 17 TONS. AN INSCRIPTION ON THE COLUMN IS ATTRIBUTED TO SEVERAL DIFFERENT PERIODS EXTENDING AS FAR BACK AS THE THIRD OR FOURTH CENTURY AFTER CHRIST

progress lie not only in the amount of new knowledge to be imparted per generation, but also in the safe limit of increase of earnings which the workmen may gain without demoralising them.

Although the Indian craftsman has fallen so low in his technique, he is by no means devoid of intelligence; anyone who has heard him driving a bargain or making excuses for bad work will be struck by his ingenuity and ready wit. This intelligence, if rightly directed, would go far to help him on the way to industrial improvement. The amount of inconvenience he will at times suffer in carrying out his religious duties, or in assuming the debt of a deceased parent, show a sense of honour that would be creditable to a man of much greater pretensions.

He is, therefore, well worth a serious effort to bring him into line with the times. But we must first fit the instruction to the man, not the man to the instruction; and the system of instruction must fit the means available for its application. The sons of artificers cannot go to a great distance for an education; the schools must, therefore, be numerous and cheap. It is fortunate that any structure that provides sufficient shelter from the weather, with adequate light and ventilation, will serve the purpose, provided that the teacher knows his work.

It is unnecessary to dwell here on the next stage of primary technical instruction,—it lies, at the least, two generations ahead of the present time. The present inquiry deals only with the instruction of the industrial class, whose efficiency has hitherto been unaffected by educational effort. The Indian artisan has to be taught to think rationally and methodically about his work,

and where this has been accomplished the industrial regeneration of India will have commenced in earnest.

Somewhat irrelevant, perhaps, but none the less interesting in connection with matters Indian, is the illustration of the famous iron pillar of Delhi, on the opposite page. It is a solid shaft of wrought iron, 16 inches in diameter, and of a length that is variously reported. The total height above ground is 22 feet, including a capital of 3½ feet. Major G. A. Cunningham, R. E., C. S. I., Director-General of the Archæological Survey of India, reported in 1863 that the total length of the pillar is upwards of 48 feet, and possibly 60 feet.

The lower diameter is 16.4 inches and the upper diameter 13.5 inches. The pillar contains about 80 cubic feet of metal, and weighs about 17 tons. The metal was for a long time reputed to be bronze, owing probably to a curious yellowish shade on the upper part. A sample from near the base was analysed by Dr. Murray Thompson and found to be pure malleable iron of 7.66 specific gravity. The metal is, of course, charcoal iron, made directly from the ore in small billets; but how it was welded up no one can tell, as no record exists of any early method of dealing with great masses of wrought iron.

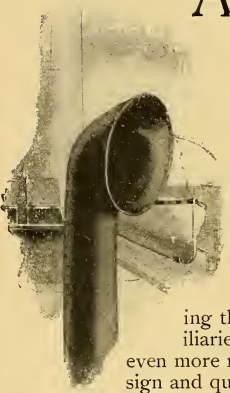
An inscription, roughly cut or punched upon the column, states that Raja Dhara subdued a people in the Surdhu, named Vahlikos, and obtained with his own arm an undivided sovereignty on the earth for a long period. The date of the inscription has been referred to the third or fourth century after Christ; but on this authorities are at variance, as the style of writing is supposed by some to belong to a later period.

According to tradition, the Iron Pillar was erected by Bilan Deo, the founder of the Tomara dynasty, who was assured by a learned Brahmin that, as the part of the pillar had been driven so deep into the ground that it rested on the head of Vasuki, King of Serpents who supports the earth, it was now immovable, and that dominion would remain in his family as long as the pillar stood. The Raja, doubting the truth of the Brahmin's statement, ordered the pillar to be dug up, when the foot was found to be wet with the blood of the serpent king. The pillar was again raised, but owing to the Raja's incredulity, no means could be found to fix it firmly, and it remained loose (dhila) in the ground, and this is said to have been the origin of the name of the ancient city of Delhi.

THE AUXILIARY MACHINERY OF STEAM VESSELS

I.—TURNING AND REVERSING ENGINES, AIR AND CIRCULATING PUMPS, CONDENSERS, FEED PUMPS, AND FEED HEATERS

By Jasper E. Cooper



AN excellent illustration of the enormous advances made in engineering during the last few years is to be found in the comparison of the auxiliary machinery of a steam vessel built, say, twenty years ago, with the auxiliaries of more recent ships. Marine engines themselves have undergone vast improvements during this time, but their auxiliaries have advanced at an even more rapid pace, both in design and quality of workmanship.

In the earlier days the workmanship expended on the auxiliary was not considered to be of the same importance as the workmanship of the main engines; in fact, to some extent that view prevails even to-day. Attention to details is usually postponed until the last, and so in this case the marine engine received the attention of engineers until it reached a certain state of efficiency; after this the auxiliaries came in for their share of consideration. It was found necessary to add to their number from time to time, much ingenuity was spent in improving the designs, and eventually the magnificent machines of a modern battleship or liner came into being.

The auxiliary machinery of a steamship can be roughly divided into three classes:—First, auxiliaries in direct connection with the main engines, such as the turning and starting engines; second, auxiliaries indirectly connected with the main engines, such as the circulators and feed pumps; third, auxiliaries not connected with the main engines, such as cranes and winches, hydraulic pumps, and others.

Commencing with the turning engine, we find that all, except the very smallest, marine engines are fitted with a machine for mechanically revolving the main shaft when the ship is in dock, or when, for any other reason, it is not safe to put steam on the main engines. Turning gear arrangements are all very much the same, and consist of a small engine bolted to the main bed-plate, or to one of the rockers, with a worm on its crankshaft engaging a worm-wheel attached to another shaft on which there is another worm which engages a worm-wheel on the main shaft. The intermediate shaft is so arranged that when the main engines are under steam, and the turning engine consequently is not required, the shaft can be thrown back, leaving the main shaft free to revolve and the worm and worm-wheel clear of each other.

In small vessels in which a special turning engine is not considered necessary the worm shaft is sometimes driven by a belt or chain from a donkey pump or any other auxiliary engine conveniently situated; but this can hardly be considered good modern practice.

Some engines, such as those of torpedo-boat destroyers, rely upon hand turning gear. A long lever is made attachable to a ratchet fixed to the worm shaft, and in the case of destroyers one man can turn the engines through one complete revolution in about five minutes. Every turning gear should be capable of being worked by hand in case

it is required to turn the engines when no steam is available.

In naval work the worm-wheels are frequently made of cast steel; but cast iron is very suitable for these wheels, and works very well with a wrought steel worm. The teeth of the worm-wheel should be machine cut, have a good clearance, and should be of such proportions that the stresses will not be excessive if only two teeth are in gear at one time. The pitch of the teeth varies from 2 inches with a small shaft to 3½ inches with the larger diameters. Wheels up to about 3 feet in diameter are usually made with a continuous disc instead of arms.

A very important auxiliary to the modern steam engine is the reversing engine. All marine engines should be fitted with some apparatus by which they can be reversed from full speed ahead to full speed astern in not more than about twenty-five seconds. It will readily be seen that, except in the case of the very smallest engines, this is impossible with the ordinary hand gear, and consequently mechanical means have to be provided.

The simplest method is to fit a steam cylinder to the ordinary hand gear, the piston pulling and pushing as required; but there are many objections to this in such a simple form; it is found that the steam is liable to master the hand power and tend to overrun its limits. One form of gear in which these difficulties have been overcome and which is in extensive use is shown in Fig. 1.

The engine is jointed to the bed-plate or column of the main engine at *A*,—the end of the steam cylinder. In this cylinder is fitted a piston with rod *C*, upon which is cottered a block piston *D*, working in the hydraulic cylinder *E*, the fluid being able to pass from one end to the other of the cylinder *E* by means of a small hole bored in the piston. The rod *C* passes through stuffing boxes on the steam and hydraulic cylinders, terminating in a joint *F* on the weigh-shaft lever *G*. The lever extends to the joint *H*, upon which works a rod and rack gearing with the pinion *J*, both being shrouded to the pitch line.

Upon the pinion shaft is keyed a worm-wheel which is actuated by the bronze worm *L*, this being revolved by the hand-wheel *M*. The worm and hand-wheel shaft are thrown out of gear with the worm-wheel *K* by the eccentric

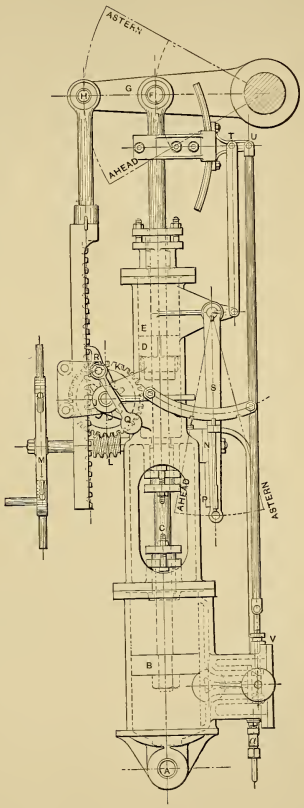


FIG. 1.—A REVERSING ENGINE

N, which, is turned by the handle *P*. When the hand-wheel and worm are disengaged the rack and worm-wheel are free to revolve on the engine making a stroke either way. This hand-gear, therefore, forms no integral part of the engine, and is unaffected by any

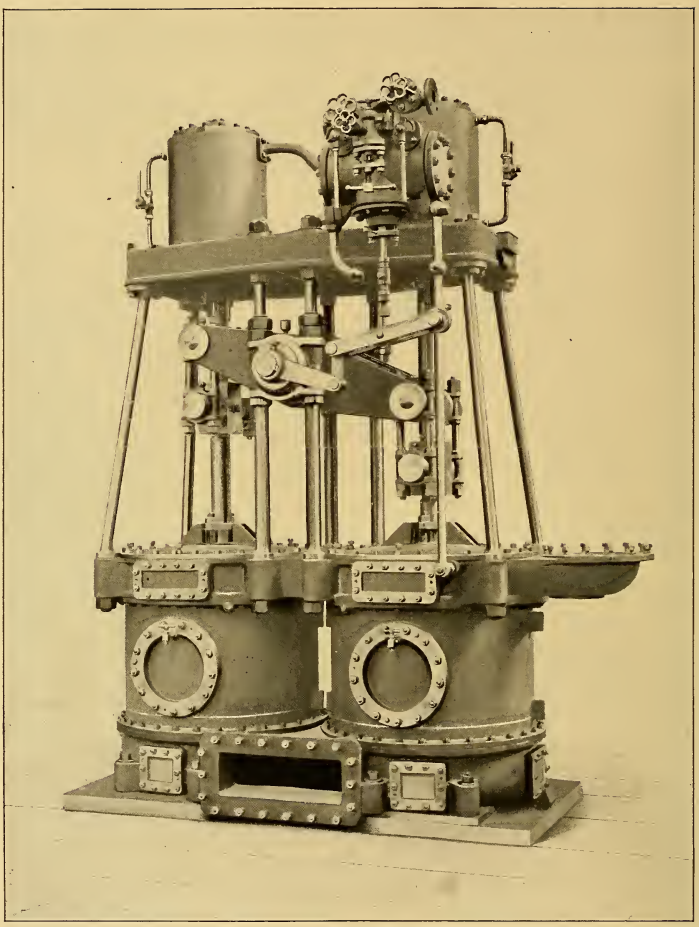


FIG. 2.—AN INDEPENDENT AIR PUMP, ADMIRALTY TYPE, MADE BY MESSRS. G. & J. WEIR, LTD., CATHCART, GLASGOW

derangement of either hydraulic or steam cylinder, or the steam valve.

A locking arrangement on the head-gear is provided, so that the main valve gear can be linked up in any position of the ahead stroke. This consists of a pawl *R*, which is made to engage the teeth of the rack, and the engine is held up against the pawl by means of the slide valve being left slightly open to steam. The pawl is provided with a balance weight so that, on the engine being reversed for the astern position, it immediately pulls the pawl out of gear. The hydraulic cylinder is kept charged by means of the condensed

steam in the bottom of the valve casing being driven by the steam through the non-return valve *a*, and led by a small copper pipe, as shown, into the lower end of the cylinder.

The engine is handled by a simple reversing lever *S*, which is connected by two links to the fulcrum of a lever at *T*. This lever has its end extended to *U*, which is connected direct by a link to the valve spindle *V*. A curved link is securely attached to the lever *TU*, and on this there slides a block which is carried on the piston rod.

The action of this valve gear is as follows:—When the lever *S* is pulled into the ahead position, the lever *TU*, which is attached to the curved link sliding in the block mentioned, is depressed. The valve spindle is also moved down, opening the top end of the cylinder to steam. The piston rod now begins to move down and carries with it the guide block which forces the end of curved link to move into the centre line of the block, thus moving the point *U* of the lever *TU* in an upward direction, the fulcrum at *T* being held stationary by means of the reversing handle *S*. In this way the valve spindle *V* is moved back into its original position, thus bringing the engine to rest. The same operation is gone through for the astern or any intermediate position.

It might be said that a balance cylinder is part of the main engines, and not an auxiliary; but the assistant cylinder is an auxiliary because it is a small engine in itself, and if the slide valve were disconnected from the eccentrics the assistant cylinder would cause it to move up and down automatically, not, perhaps, at the normal speed, because it is the duty of the eccentrics to adjust its speed, but the assistant cylinder does all the heavy work.

It might be asked, "What is this heavy work?" Well, it is made up of three separate components,—first, the dead weight of the valve has to be overcome; second, the inertia, which in many cases is greater than the dead weight, calls for a considerable force to balance it; and third, there is the friction of the valve on its seat. It is the sum of these three forces which causes the eccentrics to wear and the valve gear to knock unless an assistant cylinder is fitted.

If these forces are worked out and plotted to scale, it is found that the total force varies from a maximum tension in the valve spindle when the valve is at the top of its stroke to a maximum compression at the bottom.

The apparatus shown in Fig. 3, Joy's assistant cylinder, has been designed to overcome the difficulty. The slide rod is continued through a gland and acts

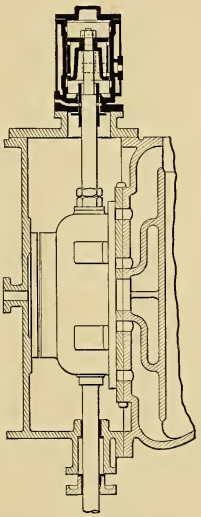


FIG. 3.—JOY'S ASSISTANT CYLINDER

as a valve for admitting steam to the under side of the piston in the balance cylinder. By an arrangement of slots in the cylinder walls a certain amount of steam is passed into the hollow piston and is carried to the top of the stroke, where it is passed to the upper side of the piston, and supplies the necessary power to overcome the tension in the rod, due to the inertia, and start the slide valve on its downward stroke. The position of the slots in the cylinder

walls and the volume of steam admitted to the hollow piston are adjusted to meet any particular cases, so that the forces set up are equal and opposite in character to those caused by the weight, inertia, and friction of the valve.

Of all James Watt's inventions the air pump is probably the most commonly used at the present time. He patented it so long ago as 1769 to use in connection with his condensing engines. It is a most important auxiliary to the marine engine, and yet we find that it is responsible for about one-fifth of the total number of engine breakdowns, which leads one to think that it has not received the attention due to it.

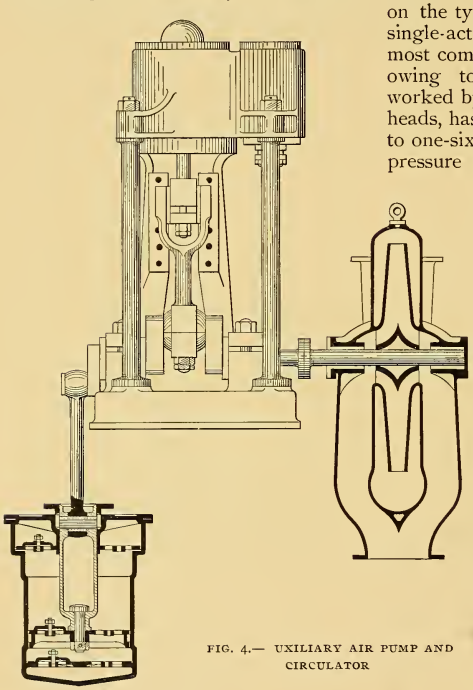


FIG. 4.— UXILIARY AIR PUMP AND CIRCULATOR

The function of the air pump is to extract the vapour, the condensed steam and the air originally contained in the feed-water when it entered the boiler, from the condenser, and, in doing this, to reduce the pressure in the condenser to as near a perfect vacuum as possible and to keep it there. In the days of the jet condenser the air pump had also to remove the condensing water in addition to the condensed steam; but marine engines with jet condensers are now a thing of the past, and for the present purpose need not be considered.

The capacity, or volume, of an air pump is largely dependent upon the conditions under which it will work and on the type of pump; but the vertical, single-acting type, which is by far the most common form used on board ship, owing to its being so conveniently worked by levers from one of the cross-heads, has generally from one-fourteenth to one-sixteenth the volume of the low-pressure cylinder. This is about twice the theoretical capacity, which is readily calculated from the amount of steam, or water, used per revolution, assuming the water to contain one-twentieth of its volume of air mechanically mixed with it.

Since the condensed water is used again and again, it would appear that the air would speedily be driven off, leaving the air pump to deal with only the condensed steam, and no doubt this would be the case if the engine worked perfectly; but water has constantly to be admitted to make up for leakages of steam, and many engineers declare that it is necessary for the efficient working of the air pump to have the pet cock open, thus admitting a continuous stream of air, which no doubt partially aërates the water. Another source of aëration is found in the air pump discharge into the hot well. This discharge is usually situated near the top of the tank, leaving the water some distance to fall under ordinary working conditions.

The period of the cycle of change, as it might be called,—that is, the time taken by a particle of water to make

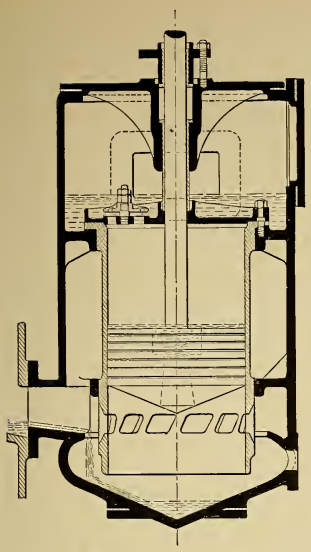


FIG. 5.—THE EDWARDS AIR PUMP. MADE BY THE EDWARDS AIR PUMP SYNDICATE, LTD., LONDON

a complete cycle through the boiler, engine, condenser, and hot well,—is, of course, dependent upon the capacity of the hot well and feed tanks, and upon the amount of water in them, and varies from 15 minutes to one hour; but 75 per cent. of this time is spent in the hot well, or feed tank, which tanks are both open to the atmosphere by an air pipe. It is not astonishing, therefore, that the water absorbs a considerable quantity of air before it again enters the boiler as feed-water.

The valves of an air pump are of much importance and should be most carefully considered. One of the great advantages of the Edwards air pump, shown in Fig. 5, is the absence of both foot and bucket valves, which are necessary in most designs of the ordinary vertical pump. The foot-valves can open only by having a greater pressure beneath than above them, and since the head of water is not sufficient to do this, it follows that the bucket must create a better vacuum in the barrel of the pump than that in the condenser before they will open. Consequently, these valves should be well designed and free from friction.

A very important item in connection with the valves is to securely lock the nuts which hold them in position. Many air pumps have broken down owing to this being overlooked. If small split pins are used, they should pass through the nut, as well as the bolt, to prevent the former from turning and so shearing the pins. Another important consideration is that the foot-valves should be below the lowest level of the condenser, so that the water will readily drain to them.

Upon examining the results of a series of progressive trials of any steamship fitted with surface condensers one is struck by the fact that the vacuum always diminishes as the engines increase in speed. This would seem to indicate that as the amount of steam used by the engines increased, the air pump became less able to deal with it, or, in other words, that the pump was not large enough. The real reason, however, is

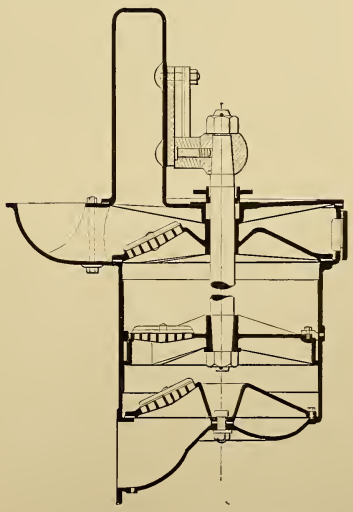


FIG. 6.—A SINGLE-ACTING AIR PUMP

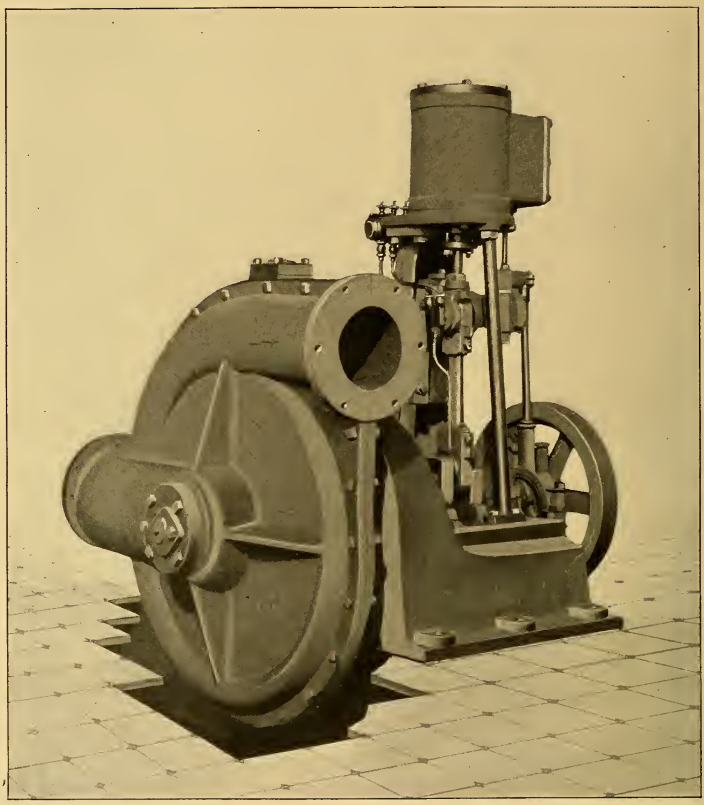


FIG. 7.—A CIRCULATING PUMP MADE BY THE MORRIS MACHINE WORKS, BALDWINSVILLE, NEW YORK

that the increase of speed causes the resistances to the passage of the water through the foot-valves, such as the friction of the valves and the inertia of the water, to be greatly augmented, thus necessitating a greater difference between the vacuum in the condenser and the vacuum in the barrel before the foot-valves lift. It is doubtful whether a larger pump would make any material difference in the vacuum at these higher speeds, and this view is supported by an examination of the vacuum obtained with engines of various types. For instance, the usual vacuum in the condenser of a torpedo-boat destroyer, running at full speed (400 revolutions), is about 23 inches; in a cruiser making 200 revolutions per minute, 24.5 inches; in a battleship making 108 revolutions at full speed, 26 inches.

The question of what packing to use in air pumps is one worthy of close attention. Metallic rings are not well suited to this class of work, as they soon wear. A bucket without any packing whatever appears to be as satisfactory as any yet tried. Buckets of this description should have small grooves turned in them for the water to lodge

in; this makes them more air-tight, and lessens the wear by tending to create a thin film of water between the barrel and bucket. Fig. 6 shows a good example of a single-acting air pump, as fitted to a large marine engine indicating 7500 H. P. The air vessel is used as a guide support for the pump crosshead.

Some air pumps, instead of being worked directly by the main engines, by means of levers attached to the crosshead by small connecting links, are entirely separate, being operated by a special engine designed for that purpose. Such separate air pumps can be designed to run at a much slower speed than the main engines, thus avoiding the loss of several inches of vacuum in the case of high-speed engines, as pointed out above. They can also be started before the main engines, which is frequently a great convenience. The advantage in steam consumption, however, is probably with the pump worked by the main engines.

Battleships and large merchant and passenger ships are usually fitted with a small condenser, air pump, and circulating pump for the auxiliary engines. Fig. 4 shows one of these air and circulating pumps. The engine and circulator rest on a bearer built out from the bulkhead, and the air pump is beneath them. The trunk above the bucket of the air pump has the effect of making the discharge more continuous, by displacing a quantity of water on its downward stroke equal to the volume of the trunk, the remaining volume being discharged on the upward stroke. Consequently, this pump will essentially become a double-acting pump if the area of the trunk is made equal to half the area of the bucket; but it has the advantage of the direction of flow being constant, which is not the case in a double-acting pump.

These auxiliary pumps are liable to have a large amount of water suddenly thrust upon them by the opening of a large drain cock leading into the condenser, or the starting of several engines at once, and if this is allowed to flow into the pump at the full bore of the suction pipe the probability is that the valves or bucket will suffer. A good method of preventing this is to fit a blank flange with a vertical slot cut in it to the suction side of the pump; this allows only a limited quantity of water to pass, the pipe acting as a reservoir for the remainder until it is all pumped to the hot well.

The centrifugal pump has now almost entirely replaced the reciprocating pump for circulating the cooling water through the condensers of a steamship. It works economically at a low lift, and is, there-

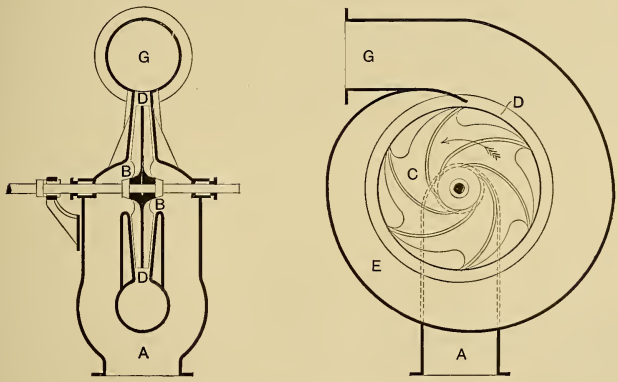


FIG. 8.—CENTRIFUGAL PUMP STATIONS

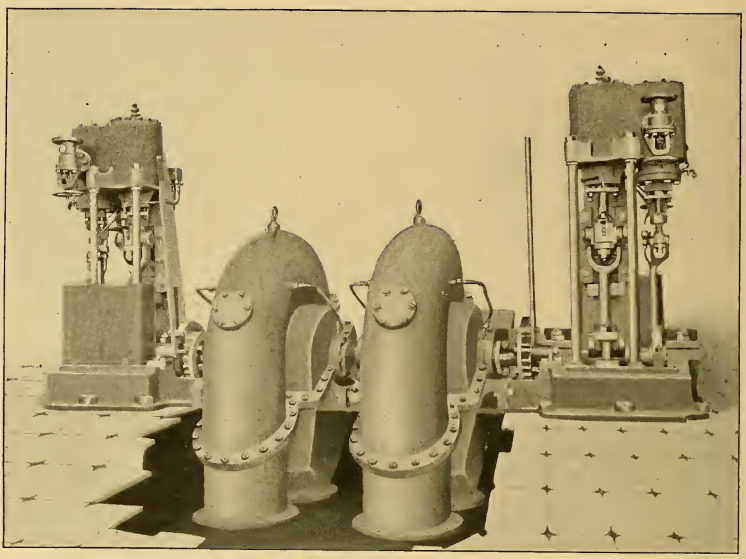


FIG. 9.—CIRCULATING PUMPS BUILT BY MESSRS. MATTHEW PAUL & CO., LTD., DUMBARTON, SCOTLAND

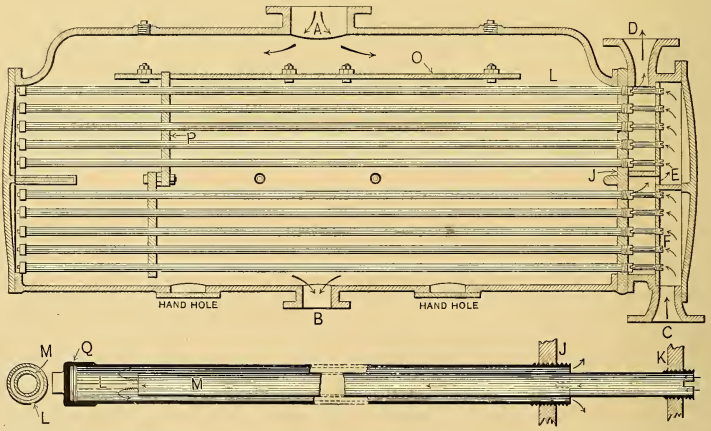


FIG. 10.—THE WHEELER CONDENSER, MADE BY THE WHEELER CONDENSER & ENGINEERING CO., NEW YORK AND LONDON

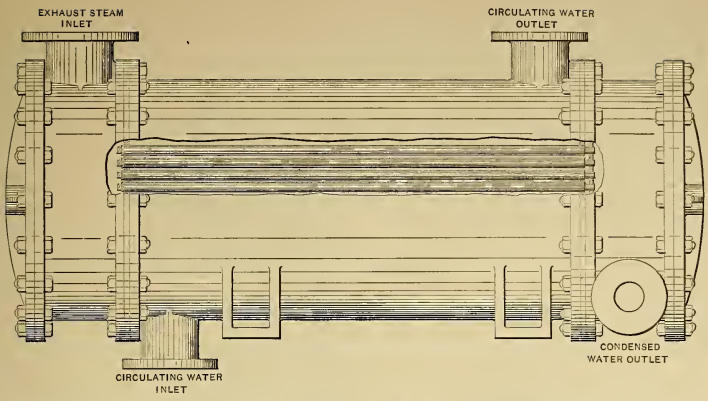


FIG. 11.—THE PAUL CONDENSER, MADE BY THE PAUL HEATER & CONDENSER CO., BOOTLE, ENGLAND

fore, very suitable for the work of a circulating pump, because the friction of the water in passing through the condenser tubes is equivalent to a low lift only. Reciprocating pumps are not economical for low lifts, and do not run so smoothly as centrifugal pumps. The latter, however, have to be filled with water before they will commence pumping, either by placing them below the sea level, as is usually done, or by creating a vacuum in the pump casing by means of a steam ejector.

Fig. 8 represents two sections through a centrifugal pump with the shaft placed horizontally. When pumping has commenced, the water enters at *A* and flows up the passages at the sides to the eye *B*. As the disc *C* rotates, the water is projected outward by the vanes, and enters the whirlpool chamber, or diffuser *D*, in which some of the energy due to the velocity of the water is converted into pressure, and from this the water passes into the volute, or spiral chamber *E*, whose section increases uniformly round the circle, so that the velocity of the water in it shall remain constant.

The disc rotates in the direction indicated by the arrow, and as it is necessary that the water should enter it without shock the vanes must be curved back at the inner diameter of the disc, because the water has very little, if any, velocity of whirl at entry. The vanes are still more inclined to the radius at the outer circumference. There is, however, considerable difference of opinion as to the most suitable value for this angle, and under certain conditions a small angle is used without sacrificing efficiency.

In the earlier centrifugal pumps no volute of gradually increasing section was fitted round the diffuser, but only a casing of uniform section. This was,

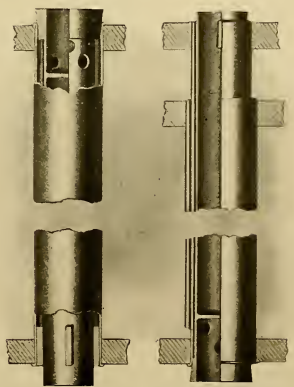


FIG. 12.—THE ARRANGEMENT OF THE PAUL CONDENSER TUBES

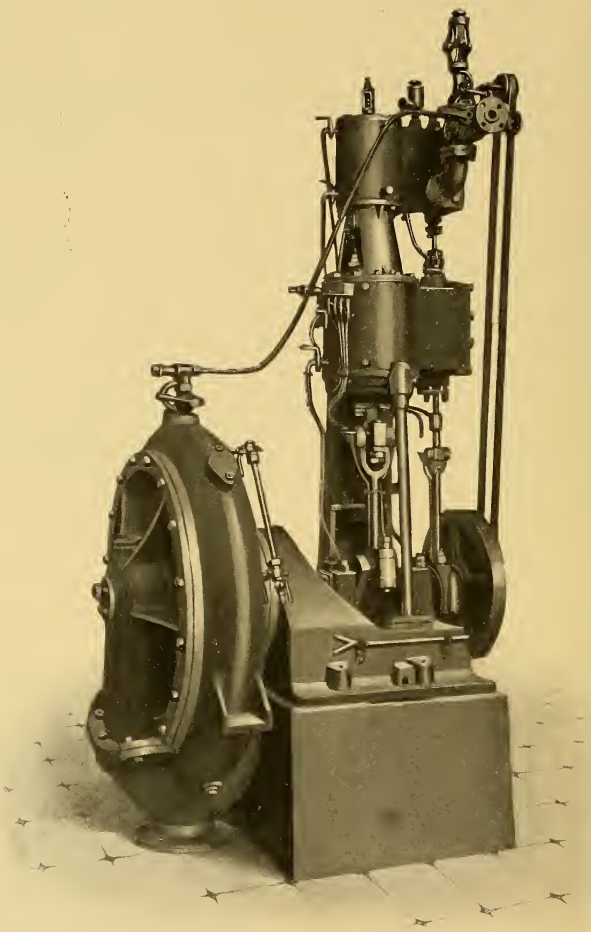


FIG. 13.—TANDEM COMPOUND ENGINE DIRECT CONNECTED TO A CENTRIFUGAL CIRCULATING PUMP. MADE BY MESSRS. DRYSDALE & CO., GLASGOW

no doubt, one of the causes of their inefficiency, because there is a certain velocity at which it is most efficient for the water to travel round the outer circumference of the disc, and unless the casing increases uniformly in section the velocity cannot be constant. The efficiency of a centrifugal pump with a lift of about 3 feet is about 50 per cent.; with a lift of 15 to 20 feet the efficiency is at its maximum of about 70 per cent.; with higher lifts it is less.

Fig. 13 shows a tandem compound engine coupled direct to a centrifugal pump, as made by Messrs. Drysdale & Co., of Glasgow. It is specially constructed with a cast iron distance piece between the two cylinders, having a gun metal sleeve through which the piston rod works, thus making only one packing gland on the piston rod instead of three.

Nearly all large war and merchant vessels have a small condenser for taking care of the steam from the auxiliary engines and winches. These latter are frequently running when the ship is in port, and when the main engines are not running. It would be waste of power to keep the large circulating pumps going under such circumstances just to condense the steam from a few auxiliaries; hence, the utility of the small condenser with its air and circulating pumps.

All auxiliary condensers are, of course, surface condensers, the surface on which the steam is condensed being metallic tubes. Copper being one of the best conductors of heat, and also highly ductile, was at first chosen as the material from which to make the tubes. But it was soon found that the fatty acids from the lubricating oil dissolved some of the copper and produced soluble salts of that metal which were pumped into the boiler with the feed-water and caused injury. The tubes were then tinned, but this adds very considerably to their cost, so that brass tubes are nearly always used now. They are sometimes tinned as an extra safeguard against salts of copper being formed, and also as a preventive of corrosion of the tubes owing to the action of the sea water.

The Paul condenser, shown in Fig. 11, made by the Paul Heater and Condenser Company, of Bootle, is designed to take the exhaust from all the winches and auxiliary machinery of a large steam vessel. Its special feature is the arrangement of the tubes. In the ordinary condenser, where the tubes are, say, $\frac{5}{8}$ inch internal diameter, the steam is led into the body of the condenser and there left

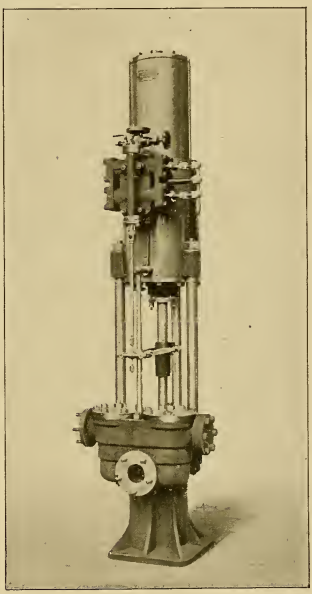


FIG. 14.—A MARINE BOILER FEED PUMP MADE BY MESSRS. J. P. HALL & SONS, LTD., PETERBOROUGH, ENGLAND

to take its chance as to whether it actually comes into contact with the cooling surface or not; and the cooling water which is circulated through the tubes, soon becomes warm on its outer surface, although the core may be quite cold and remain so until it leaves the tube, thus wasting a considerable amount of the cooling effect of the water. In the Paul condenser, however, the tubes are arranged as shown at the left of Fig. 12.

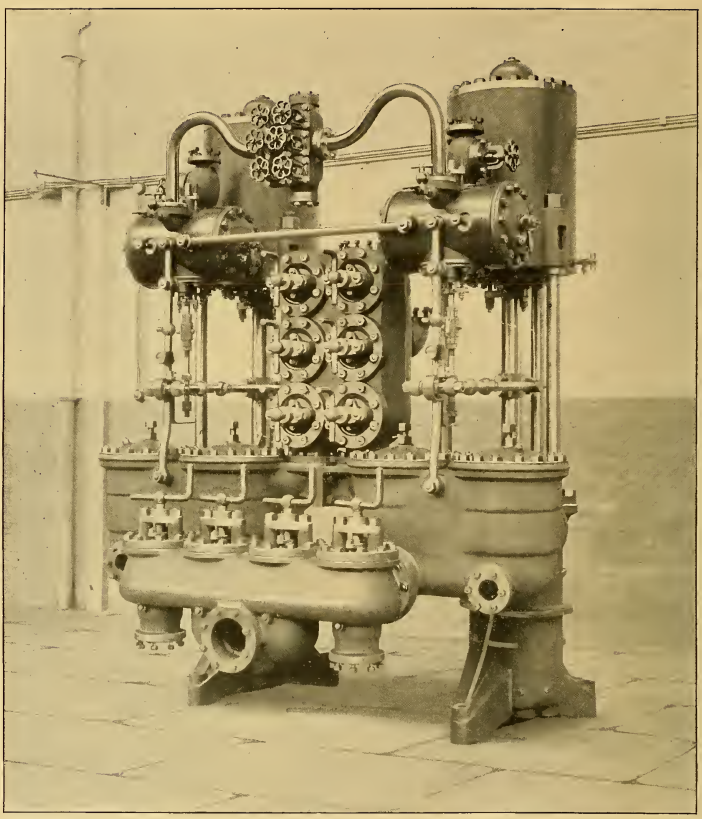


FIG. 15.—DIRECT-ACTING FEED PUMPS FOR MERCHANT SERVICE. MADE BY MESSRS. G. & J. WEIR, LTD.

The core of the tube is not used at all, but the steam is split up into a thin ring, and so made to come into intimate contact with the cooling surface. The water is circulated outside the tubes, and it is found in practice that 15 pounds of circulating water per pound condensed are sufficient, also that 30 pounds of steam are condensed per square foot of cooling surface per hour. In condensers for land engines where the quantity of cooling water is limited the arrangement shown at the right of Fig. 12 is used. Here the circulating water is split up into ring form, as also is the steam. The tubes and tube-plates are of brass and the body of cast iron, unless a brass body is specially desired.

In the Wheeler condenser, shown in Fig. 10, the steam, entering at *A*, is condensed as in an ordinary condenser by coming into contact with the cold tubes. The circulating water enters at *C* and then travels down the inner tube *M* and returns along the space between the tubes *M* and *L*. This operation is repeated with the upper group of tubes. The object of this arrangement is to

make a back tube-plate unnecessary. One of the most important points in connection with the feed pumps of a steam vessel is that they must be reliable, as a breakdown of the feeding apparatus may be attended with the most serious consequences. The great increase in the boiler pressures of late years, and the introduction of water-tube boilers which store only sufficient water for running a few minutes, has made the duty of the feed pump a most important one; it works as continuously as the main engines, and often under the most severe conditions.

Independent pumps are now nearly always fitted to large ships, and although the old style of pump, working off the air pump lever, is frequently fitted to merchant ships, it is usually considered as only a spare arrangement for use in case of accident to the main feed pumps.

A great deal has been written of late as to the wasteful character of the auxiliary machines of steamships, and the feed pump has, of course, received its share of criticism; but although it is not as economical as one would wish, it is not, by any means, the worst offender in this respect. Various improvements in design and workmanship during the last few years have done much to raise the efficiency without adding to complexity or first cost. Compounding has been tried, but in marine work the compounding of feed pumps by an additional cylinder has not been considered advisable, as the simpler and less complicated the pump is, the better. It is no doubt more economical to work the pumps

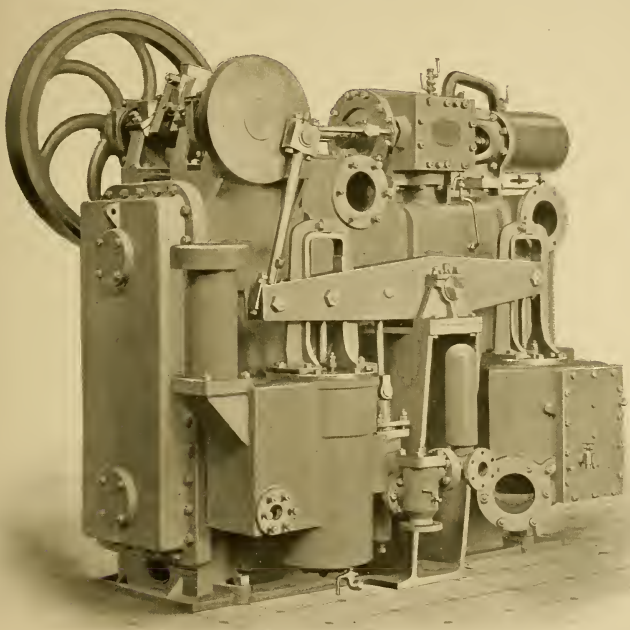


FIG. 16.—SURFACE CONDENSER WITH AIR, CIRCULATING, AND FEED PUMPS, MADE BY MESSRS. CAMPBELL & CALDERWOOD, PAISLEY, SCOTLAND

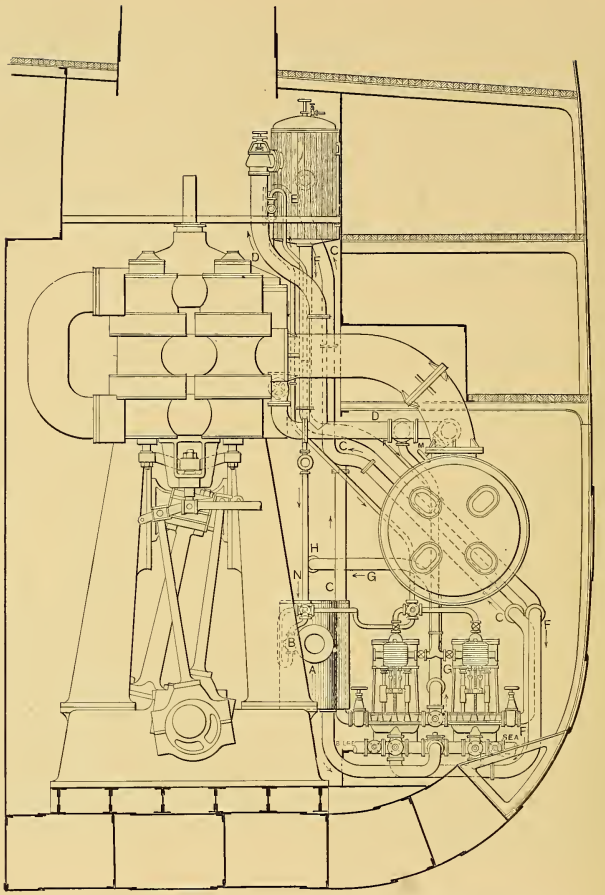


FIG. 17.—DIAGRAM SHOWING A TYPICAL ARRANGEMENT OF CONDENSER, HOT WELL, WORTHINGTON FEED HEATER, AND BOILER FEED PUMPS ON BOARD SHIP

compound than single, as with any other engines; but the waste steam can be utilised without compounding, and almost the same economy obtained, by using an exhaust steam feed heater.

Of the several pumps on the market Weir's are probably as well known as any in Great Britain. The British Admiralty are now using them on most of the new ships. Fig. 15 represents a pair of pumps designed for merchant service.

Another very satisfactory pump for marine use is the Worthington, shown in Fig. 18. It is designed specially for main boiler feed where a very high steam pressure is carried. The water passages are free and direct, and the water valves are arranged in boxes at the front of the pump so as to be easily accessible and

allow the pump to be placed close against a bulkhead, as it is unnecessary to allow for any space at the back or sides for examination. The suction and delivery valves are in separate boxes, so that one can be examined without disturbing the others, and they are so placed that the pump can free itself of vapour when pumping hot water. The couplings on the rods between the steam and water pistons allow of the water pistons being removed without disturbing either the steam cylinders or the valve motion. A specially light form of this pump is made for torpedo-boat destroyer service, or any other case where weight is of great importance.

Fig. 17 shows a general arrangement of Worthington automatic feed pumps and heater. The steam condensed in the surface condenser is delivered by the air pumps into the hot well, marked *A*. This delivery being intermittent, it is necessary to regulate the working of the pumps, in order to ensure their always being completely filled with water. In the hot well there is, therefore, a float which operates the valve *B* and controls the working of one of the pumps, gradually opening the valve as the water rises in the hot well, and shutting it off in case the water is not delivered over as fast as the pumps take it away. The pump in connection with the hot well delivers the water through the pipe *C* into the heater through a spray valve, which will be described later in connection with feed heaters.

The exhaust steam from the various auxiliaries, which is turned into the main exhaust trunk *D*, is conveyed to the heater where it thoroughly mixes with and imparts its heat to the feed-water. The water, as it accumulates in the heater, raises the float, which opens the steam valve *E* controlling the second pump, and, passing from the heater down through the pipe *F* to this second pump, is forced by it into the feed supply *G* leading to the boilers through the bulkhead.

The feed heater has lately taken a very prominent position amongst the auxiliary machinery of a steamship. Its importance has been recognised since about 1888, when it appears that the

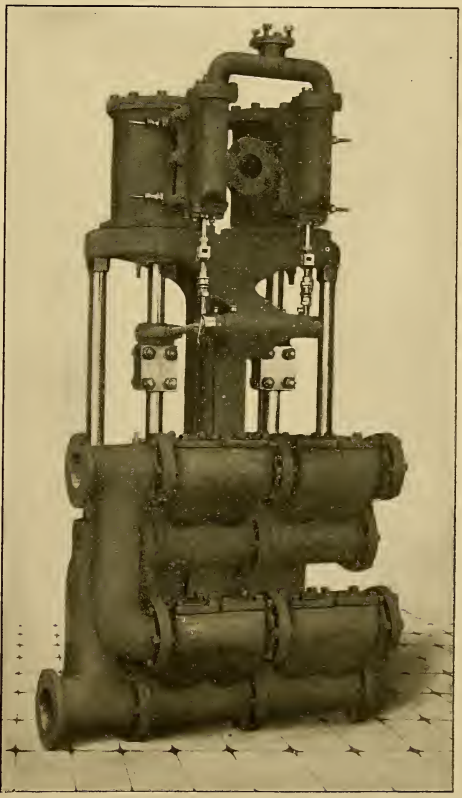


FIG. 18.—THE LATEST IMPROVED VERTICAL DUPLEX MARINE FEED PUMP MADE BY HENRY R. WORTHINGTON, NEW YORK, ADMIRALTY PATTERN. SUITABLE FOR STEAM PRESSURES AS HIGH AS 250 AND 300 LBS. PER SQUARE INCH

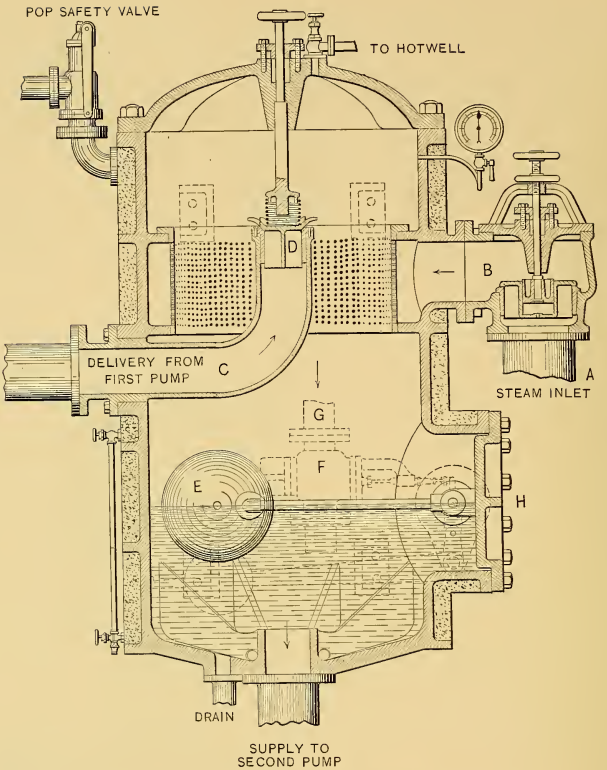


FIG. 19.—SECTIONAL VIEW OF A WORTHINGTON MARINE FEED HEATER

heating of the feed-water by means of steam taken from a small donkey boiler was suggested, not with the idea of saving coal, but to save the wear in the boiler. The live steam heater was tried, and, to the surprise of engineers of all grades, it was found to effect considerable economy in the coal consumption. This was at first discredited; but as the results, one after another, were found to all point to a saving, the fact was at length admitted to be a fact and entered as such in the great book of experience.

An illustration of the good effects of a feed heater occurred a short time ago on the trial of a small steam vessel. The boilers were being forced to their utmost, but they could not be persuaded to keep up the necessary pressure of steam. The writer suggested connecting the high-pressure receiver drain cock with the feed tank, and by this means heating the feed-water. This was done, and by the help of a piece of copper pipe, made into a small coil inside the feed tank, the live steam was admitted and the temperature of the feed-water raised. The result was above expectations. The boilers, after a short time, kept steam with comparative ease. As an outcome of this a feed heater of a rather more elaborate design was fitted

without delay. This primitive makeshift was a live steam heater. Another system of feed-heating consists of an apparatus in which the steam, taken from one of the receivers of the main engines, is mixed with the feed-water, thus giving up its heat to the latter, a great quantity of which would otherwise be pumped overboard in the circulating water if the steam were allowed to continue its path through the condenser.

A third method of heating the feed-water is to either mix it with the exhaust steam from the auxiliaries or to pass this exhaust steam through tubes and circulate the feed-water round them.

A fourth system is by means of a series of tubes placed in the uptake, or above the boiler, through which the feed-water is circulated. Heat is by this means taken from the waste gases of combustion. The economisers of Belleville boilers are feed heaters of this type, and from the acknowledged superiority of the boiler with economisers to the boiler without them it is evident that feed-heating by the heat from the waste gases can be successfully applied to marine work; but in most boilers the difficulty with this style of heater is the deposit of soot on the tubes. This soot becomes quite hard and greatly reduces the efficiency of the heater.

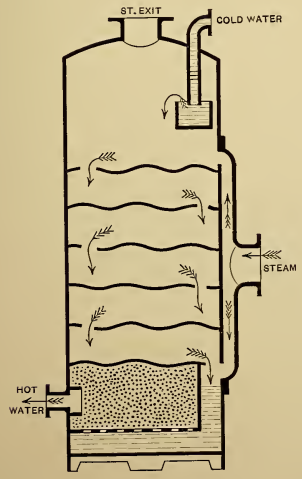


FIG. 20.—BAILEY'S FEED HEATER

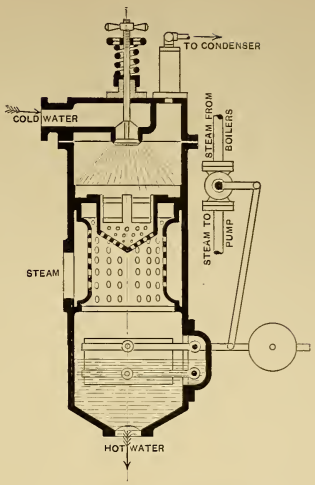


FIG. 21.—WEIR'S FEED HEATER

Coming now to a few of the many feed heaters on the market, we have, in Fig. 21, a diagram of the Weir form of heater. The heating steam is taken from the low-pressure receiver of the main engines and the exhaust of the auxiliary engines; it is led into the heater through a non-return valve on the side of the apparatus. A circular ring and conical spray piece with perforations are fitted to thoroughly mix the water and the steam. The feed-water is forced by pumps through the spring loaded valve at the top of the apparatus. As the pressure in the heater is usually less than that of the entering water, the effect of this sudden lowering of the pressure and sudden contact with the hot steam is to liberate the air in the water; this air is removed to the condenser through the small cock shown on the top of the air vessel.

The float shown in the lower part of the heater is a pan with water-tight bottom and sides, but open at the top. It is suspended on two levers, so as to

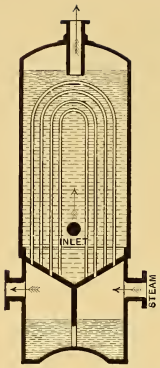


FIG. 22.—WRIGHT'S FEED HEATER

move up and down with a parallel motion; the top lever spindle is carried through the door at one end, and is balanced by a lever and weight. The float is always full of water, and the weight is adjusted to balance when one-half is immersed in the water. A lever attached to the weight lever actuates the throttle valve, as shown, and controls the supply of steam to the pumps drawing the water from the heater. A relief valve and the necessary pressure gauges are also fitted to the heater.

The Worthington heater, as will be seen from Fig. 19, is constructed upon much the same lines as the last. The exhaust steam from the auxiliaries, or live steam as the case may be, enters into an annular chamber and through perforated plates into the heater. The feed-water from the hot well enters through the pipe *C*, and is sprayed throughout the upper part of the heater by the loaded valve shown. The water condenses the steam and absorbs its heat; it is then led away to the second pump from the bottom connection. A slight vacuum is formed in the heater by this condensation which facilitates the flow of the steam.

FIG. 24.—HAMPSON'S FEED HEATER

As the water collects in the bottom of the heater it lifts the float, which actuates the valve shown dotted and admits steam to the second pump. The valve *F* is so constructed that there is no external gland which might give trouble or cause leakage into the engine room; any slight leakage there might be in the valve goes into the heater. The float is tested to an external pressure of 200 pounds per square inch. It can be easily removed through the door shown, and the head of the heater is so arranged that it can be removed for examination without breaking any joints, with the exception of the small pipe leading to the condenser.

FIG. 23.—ROW TUBES FOR A FEED HEATER

The feed heater shown in Fig. 20 is of a peculiar and novel design. It consists of a wrought-iron cylindrical shell with internal corrugated shelves. The water, upon entering, first falls into a box, and, spraying over the edge, falls from shelf to shelf, as indicated by the arrows, until it reaches the bottom, when it rises through a filter to the outlet branch. The exhaust steam from the auxiliaries enters on one side of the barrel, as shown. It is claimed for this heater that it extracts the lime from the water and so lessens scale in the boiler.

The filtering medium is pressed hay or straw.

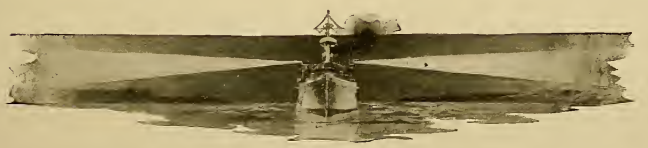
In the Wright heater, shown in Fig. 22, the exhaust steam passes through a number of bent tubes which are expanded into a tube-plate as shown. The water enters just above the tube-plate, and is drawn off the top. The outlet pipe descends below the surface of the water to avoid any scum which might accumulate on the surface.

The Row heater is of special interest, owing to the peculiar shape of the tubes. It is made by Messrs. Royles, Ltd., of Irlam. The Row tube, as shown in Fig. 23, is formed by indenting a circular tube in a regular manner. The indentations are curved in section, and are arranged at right angles to one another, so that a fluid passing through the tube is thoroughly broken up and comes into contact with a large amount of impinging surface.

The proportion of indented tube surface in practice for live steam feed heaters is 1.5 square feet per 1000 pounds of feed per hour heated from 100 to 212 degrees F. The Row tube has, in addition to efficiency, a further advantage. Owing to its shape, it is elastic in the direction of its length, and can, therefore, be secured between tube-plates without fear of a leak. Owing also to this elasticity, it readily throws off any scale deposited upon it.

Fig. 24 shows the Hampson feed heater. It is made either as a live or exhaust steam heater, and the advantages claimed by the makers are mechanical simplicity, efficiency, absence of leaky joints, and freeness from scale. The tubes are bent into the wavy form shown by a special apparatus. They are expanded into a single tube-plate, leaving them free to expand or contract, and thus ensure a good joint. A special feature is the wavy shape of the tubes, This not only ensures all the steam being brought into contact with the cool surfaces, by breaking it up, but also, owing to the constant movement of the tubes, due to expansion and contraction, the adhering of scale on the outer surfaces is prevented. The casing surrounding the tubes can be lifted off without disturbing the lower cover joint, but even this would probably not have to be done very frequently.

The concluding portion of this article, to be printed in the August number, deals with feed-water filters, steering gear, and evaporating, distilling, and refrigerating machinery.



ELECTRIC SHOCKS

By Archibald Wilson

TIME was when the mention of electric shocks suggested merely the sensations experienced in grasping the handles of the ordinary induction coil, or in receiving the discharge of a Leyden jar. There are few persons who have not allowed an electric current to be passed through them by one or the other of the above means, and the sensations need scarcely be described. While the effect is usually of a mild and harmless nature, it is well known that shocks of an unpleasant character, and even dangerous to human life, may be applied even by such simple apparatus.

With the widespread adoption of electricity for domestic and industrial uses there have appeared occasionally in the public press notices of accidents due to electric shocks, sometimes attended with fatal results. Fortunately such accidents are infrequent, but the fact that they have occurred at all accounts for the question so often raised as to whether the employment of electricity is accompanied by risk to human life. The object of this article is to allay any apprehensions on the subject, and to point out the extremely improbable conditions under which accidental contact with electric wires can result in dangerous shock.

As the fact that an electric shock has been received by anyone implies that current has passed through a portion of the body, it may be well first to explain briefly the fundamental law which governs the flow of an electric current through any substance. This is known as Ohm's law, named after the eminent physicist who first enunciated it, and is of first importance to all who are even slightly interested in electrical matters. It may be briefly stated as follows:— The number of ampères (or amount of current) flowing along a circuit is equal to the number of volts (or electrical pressure) which is applied at the ends of the circuit, divided by the number of ohms of resistance in the circuit. By circuit is meant any path along which the current is flowing, and it may consist of a copper wire, the human body or any other substance capable of conducting electricity.

Resistance is the quality possessed by every substance, in a greater or lesser degree, of impeding the flow of current through it, and is somewhat analogous to mechanical friction. Just as friction makes it difficult to drag a heavy weight over rough ground, so does the electrical resistance of a body oppose the passage of a current, and in both cases heat is evolved as the result of the work done. From Ohm's law, accordingly, can be calculated, by simple division, the amount of current flowing through any body, provided the pressure and the resistance of the body are known.

Take, for example, the case of a person touching with the points of the forefingers two electric lighting wires with a pressure of fifty volts between them. The resistance from finger tip to finger tip would probably be about 50,000 ohms. Dividing the number of volts by the number of ohms, and it is found that the current would be one one-thousandth of an ampère, or, as it is technically termed, one milli-ampère. With a pressure of 100 volts, the current would be double, or equal to two milli-ampères; with 200 volts, four milli-ampères, while with double the resistance the current

would be correspondingly halved. In other words, the greater the pressure, the greater will be the current, while the greater the resistance of the circuit so will the current be less.

A clear understanding of this simple law will enable the reader to appreciate more fully how the effect of electric shocks varies with the pressure at which current is supplied, and also with the resistance offered by the body. It will be readily understood from what has been said that the sensations of shock are more easily experienced with high than with low pressures, while if the resistance of the body be abnormally low shocks will be felt which, under ordinary conditions, would be imperceptible.

Electricity is best known to the general public in connection with its applications to telegraphy, telephony, lighting, motor driving, and street railway work. Of these the first two will not be considered, as the currents employed are slight and the risk of shock is practically negligible. In the case of the other applications comparatively high pressures and heavy currents are employed, and as the wires along which the currents are conducted have to be introduced into dwelling houses and factories, and, for street railway work, suspended over the thoroughfares, the question as to the possibility of receiving shock from contact with them is naturally one of common interest.

In the early days of electric lighting the pressure employed for interior illumination was generally limited to about 100 volts. At present, however, the pressure is usually higher,—seldom less than 200, but not exceeding 250 volts. If, as is generally the case in municipal lighting, what is known as the "three-wire" system of distributing current from the central station is employed, the current is actually generated at double the pressure used at the lamps. As the name implies, three wires are employed to form the main conductors between the station and the buildings to be illuminated. Two of these wires are called the "outers," and have the full pressure of, it may be, 500 volts between them. The third or "middle" wire forms, as it were, an intermediate stage in the range of pressure, so that between it and either of the two "outers" there is maintained a pressure of 250 volts. In lighting from these supply mains, one of the outers and the middle wire are led into the building and there suitably connected to the wiring system by which current is conveyed to the lamps.

The details of an ordinary house installation need not be here described. It is sufficient to point out that all wires employed are first covered with India rubber or other suitable insulating material so that there may be no leakage of current from them. They are then laid, for the purpose of protection from mechanical injury as well as for the sake of appearance, in grooved wood casing or in special conduits. At all points where the wires issue from the casings for the attachment of fittings or switches the metal parts to which they are attached are covered up, so that at first sight it would appear that bodily contact with the wires could not be accidentally made.

If both wires of the installation were thoroughly insulated, it would be possible to receive a shock only by touching both of them simultaneously. In most three-wire systems, however, the "middle" wire is connected to earth, which is a comparatively good conductor. In consequence the pressure between earth and either of the outers is the same as between the middle wire and an outer. A person standing on moist ground, or in any similar position which puts him in good contact with the earth, and touching a wire connected with one of the outers, would allow current to pass through him from the point of contact to earth. If his contact with the earth were bad and the resistance consequently high, the current might be so small as to be inappreciable. This is found to be the case in ordinary dwelling houses where the dry floors and carpets are of sufficiently high resistance to prevent any perceptible current from flowing to earth.

If the resistance were low, as might be the case in damp cellars, or if the floors were constructed of metal work,

the current would be of greater amount and would probably give an unpleasant shock. So long as the insulation and protection of the wires and fittings remain perfect accidental shock in this way is impossible. Occasion, however, may, and sometimes does, arise when the insulation becomes imperfect. When that occurs and the wires are enclosed in wood casing, which in its normally dry condition is a fairly good insulator, there is small likelihood of shocks being inflicted. When, however, they are enclosed in metallic tubing, it is quite possible that the insulation of one of the wires might be damaged, and the wire itself might in consequence come in contact with the pipe.

If suitable precautions were not taken, the result would be that anyone standing in contact with a good earth and touching the pipe, which would be at the same pressure as the wire whose insulation was defective, would receive a shock. This risk can be totally obviated by connecting the system of pipe work to earth. When that is done, and in all installations where piping is used it ought to be done, then if there is accidental contact between the piping and the wire which is connected to the outer side of the system, so large a current would flow across the point of contact that the safety fuses with which all electric light installations are provided would immediately act and automatically cut off the supply. The risk of shock would thus be removed almost as soon as it had arisen.

It follows, therefore, that in such a lighting system it is possible to receive an accidental shock only if four conditions are simultaneously fulfilled. First, there must be metallic connection between one of the wires and the pipe in which it is enclosed; second, the individual must be touching that section of the piping; third, another part of the individual must be in connection with the earth through a path of low resistance; and fourth, the pipe itself must not be connected to earth. It is unlikely that the first three conditions would all be complied with at the same time; but in any case the omission of the fourth, by the systematic earthing of the piping, would totally obviate all risk of shock.

It is the usual custom to earth the piping at one or two convenient points only, by means of a copper wire soldered or bolted to water pipes or other metallic earth connection. Then, by fitting up the piping in one complete system without a break in its continuity no section of it can become "live" by contact with the wires without the supply being promptly cut off.

A shock from accidental contact with wires at pressures up to 250 volts under ordinary conditions, although unpleasant to most persons, is usually harmless. Conditions must be abnormal to render shock at these low pressures dangerous. While the general public have little experience of the subject, the receipt of shocks is an every-day occurrence with men engaged in electrical work, and is regarded with comparative indifference.

When electricity is employed for motor driving the pressure used is frequently as high as 500 volts, and with three-wire systems the motor, if not of very small size, is connected to the two outers. In this case, again, the earthing of all pipework is of vital importance, as is also the careful enclosing of all parts which are connected with the supply wires. Contact with either of the wires and a good earth will produce shock at 250 volts, and contact with both wires will apply the full pressure of 500 volts. As shock at the latter pressure is decidedly unpleasant even to the most hardened electrician, stricter precautions should be taken to ensure that the work has been properly executed.

In electric street railway working the standard pressure is usually 500 volts, and current is supplied to the cars through a bare copper wire supported on insulators and stretched overhead along the routes. Only one wire is employed, and the current is returned to the supply station by means of the rails. In this class of work risk of shock may arise in two ways. Telegraph or telephone wires crossing the route of the railway may fall into the street, and in their fall may become "live" through

contact with the trolley wire; or the trolley wire may break away from its supports and fall to the ground. Both contingencies are so well provided against that injuries from shock are of very rare occurrence.

As a protection from fallen telephone wires there is sometimes stretched parallel to the trolley wire, and a short distance above it, a galvanised steel wire. This guard wire is earthed at frequent intervals; the result is that a fallen telephone wire is either held altogether clear of the trolley wire, or should it come in contact with it, the current from the trolley wire, passing through the telephone and guard wires to earth, is so excessive that the safety fuses or other automatic devices are put into action and cut off the supply from the section in which the accident has occurred. Should the trolley wire break, the current can be cut off by section switches fitted for the purpose along the route, and in many electric railway systems the cars are provided with emergency switches by which the driver, in the event of a wire breaking, can connect the system to earth, and so cut off the supply through the action of the safety devices.

In the case of the very high pressures used in long-distance transmission of electric power, the mains in such systems are generally, within city limits, placed underground, and the current is transformed to low pressures before being introduced into buildings for lighting or motor driving. Such accidents as have occurred with high-pressure systems have, with few exceptions, been confined to the operatives employed in their working.

With continuous currents the sensations to which shocks give rise are, generally speaking, in proportion to the amount of current which passes; but they depend also on the extent of surface of the body on which contact has been made. Thus a current, barely perceptible if the whole surface of the hand be used to make contact, might be quite unpleasant if passed through the finger tips. Susceptibility of persons to shock varies considerably with the individual, apparently on account of variations in the hardness and moistness of the skin, the resistance of which forms a large proportion of the total resistance of the body.

In recent measurements of several individuals the resistance from forefinger to forefinger ranged from 70,000 to 25,000 ohms; when the points of contact were moistened with saliva these figures were reduced to 40,000 and 15,000, respectively. The same individuals were made to stand on a wet iron rail, which was intended to represent a good earth connection, while a piece of copper about the size of an ordinary trolley wire was grasped in one hand well moistened. Here the resistances were found to vary from 8000 ohms to 3000 ohms, depending partly on the individual under test, and also to some extent on the thickness and wetness of the boots which were worn.

The sensations from shocks at various voltages can be learned only from experience. The writer, who, it should be noted, is not particularly sensitive to shock, can feel nothing when touching two wires at 100 volts pressure unless the fingers are moistened; then a slight prickling sensation is felt. Touching a 200-volt circuit with dry fingers gives a sharp tingle and a sensation of burning; at 400 volts the effect is unbearable. More sensitive persons, however, find the shock from 100 volts extremely discomposing, and although no danger may be incurred, it is inadvisable, unless one is thoroughly versed in the subject, to submit deliberately to shock even at that comparatively low pressure.

Cases of fatal shock are, fortunately, of rare occurrence, and are mostly confined to those employed in the generation and distribution of electricity. As can be readily understood, it is difficult to ascertain the minimum strength of current which is dangerous to life, as there is so much variation in the effect according to the circumstances attending the shock. Currents of 30 to 40 milli-ampères are probably as much as can be borne without great discomfort, although we find it stated that for medical purposes, and, of course, with due

precautions, as many as 200 milliampères can be safely passed through the human body. The effect is, however, modified so much by the state of health of the individual, by the length of time during which shock has been inflicted, and by the path which the current has taken through the body, that no definite safe limit can be positively laid down.

As a general rule, the resistance of the human body is normally so high that with pressures not exceeding 500 volts accidental contacts are rarely fatal shocks, although occasionally the portions of the body on which contact is made are severely burnt. The few fatal accidents which have occurred at low pressures appear to have been attended by a body resistance far below that usually met with. The effect of a shock may also be to cause such muscular contractions that the victim is unable to let go of the conductor which he has grasped, and, if help is not at hand, death may result from the prolonged application of a current which, if it had been only momentary, might have been comparatively harmless. On the other hand, there are on record cases of shock at pressures of several thousands of volts in which death has not resulted.

The ultimate cause of death, when due primarily to electric shock, is generally considered to be stoppage of the action of the heart or of the respiratory organs. That the latter may be affected is shown by the fact that victims of electric shock are sometimes brought to by the practice of some of the well-known methods of artificial respiration. The cessation of the heart's action may be due to stimulation of the nerves which control the beating of the heart; these, when stimulated to excess, may cause the heart to stop altogether.

The reports which appeared not long ago in the newspapers of an accident resulting in death from shock which occurred at some public baths, attracted considerable attention, and were calculated to prejudice the public against electric lighting. The facts of the case were as follows:—The baths were enclosed in cubicles, divided from one another by slate partitions which were held in position by an iron framework attached to the upper edges of the slate. The wires for the lighting of the baths were contained in metal tubing which rested on this iron framing. On the evening of the accident the attendant heard a cry, and on entering one of the cubicles discovered its occupant standing in the bath with his hands grasping the iron framework on the top of the partition. The current was switched off as soon as possible, but the man had become insensible and never recovered consciousness.

Shortly after, when the other cubicles were examined, a second man was found unconscious, and in his case also death ensued. At the coroner's inquest it was shown that alternating current was used with a pressure of 200 volts. The pipe system was earthed at one or more points; but, owing to a break in the continuity of the pipe, that section of the pipe where the accident had taken place was not connected to earth. A faulty wire had made contact with this pipe, so that both the pipe and the ironwork on which it rested were "live" at a pressure of 200 volts from earth, while both were insulated from earth by the slate on which they were supported.

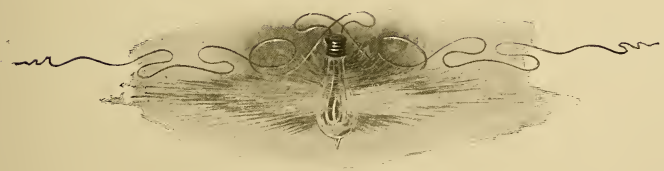
The bath was fitted with a metal waste pipe which served as a very efficient earth connection, with the result that from the man's hands, on the iron framework, to his feet immersed in water and resting on or near the waste pipe, there was provided a path of low resistance for the passage of current through his body. The resistance was probably much lowered by the presence of soda in the bath, by the large surface of the body exposed to the water, and by the moist state of the hands and of the ironwork. The resistance of the writer when tested under conditions approximately the same, namely, while standing in a bath of soapy water about 8 inches deep and with both hands grasping a piece of iron pipe, measured about 1000 ohms. This, as compared with the other measurements cited, is extremely low, and would, with a pressure of 200 volts,

result in a current of 200 milliampères flowing through the body.

The lapse of time before the current was switched off no doubt contributed to the fatal result, while medical evidence showed that the action of the heart in one of the victims was probably weakened owing to the presence in the stomach of a large quantity of undigested food. It is probable that both men were in a very susceptible condition, for several bathers stated at the inquest that, by grasping the ironwork on the partitions, they also had received shocks, but without injurious results.

The obvious moral to be drawn from this incident is the importance of thoroughly earthing the entire system of piping. Had this been properly done in the above-mentioned bath installation, the accident could not have occurred. Perfect safety can easily be secured by insisting on a high standard of workmanship.

Although the dangers of electric shock have, of necessity, been referred to at some length, it must on no account be taken for granted that accidents are of frequent occurrence. As a matter of fact, considering the enormous extent to which electricity is employed, they are extremely rare.



MILLING AS A METHOD OF MACHINING

ITS DEVELOPMENT IN AMERICAN SHOP PRACTICE

By Charles S. Gingrich, M. E.

DURING the past few years, say since 1898, there has been a complete revolution in American shop methods and machine tools, caused by the impetus given to all lines of manufacture and the unprecedented demand for machinery which followed. When factories and machine shops suddenly found themselves overwhelmed with orders, which there was no possibility of filling within a reasonable time, and with no signs of "let up" in the orders coming in, it simply meant that old methods and old tools had to be abandoned and radical changes made in all departments. Hence the revolution.

Its sweeping nature can, perhaps, be best expressed by assuming that a man who, let us say, was thoroughly up to date in all that pertained to tools and manufacture five years ago, but has been completely out of touch with the subject ever since, were to step into some of the progressive shops. He would find

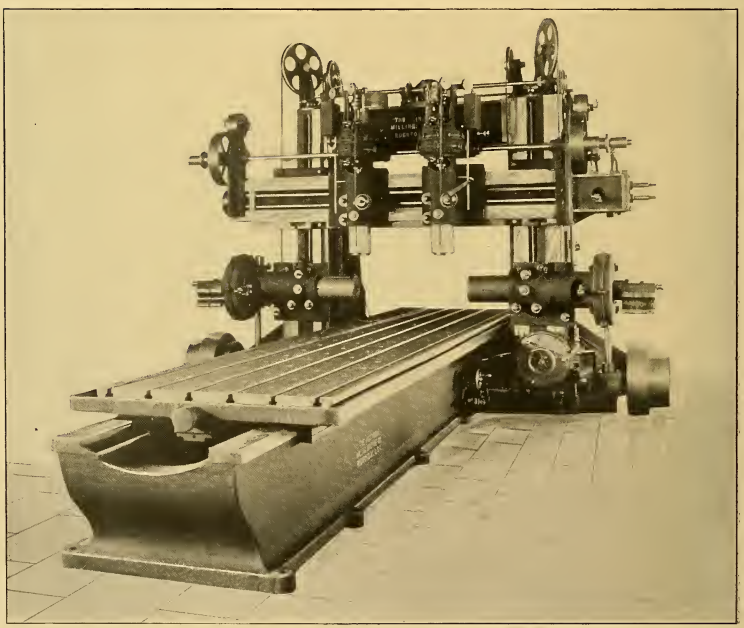


FIG. 1.—A FOUR-SPINDLE PLANER TYPE MILLER MADE BY THE INGERSOLL MILLING MACHINE COMPANY, ROCKFORD, ILL., U. S. A.

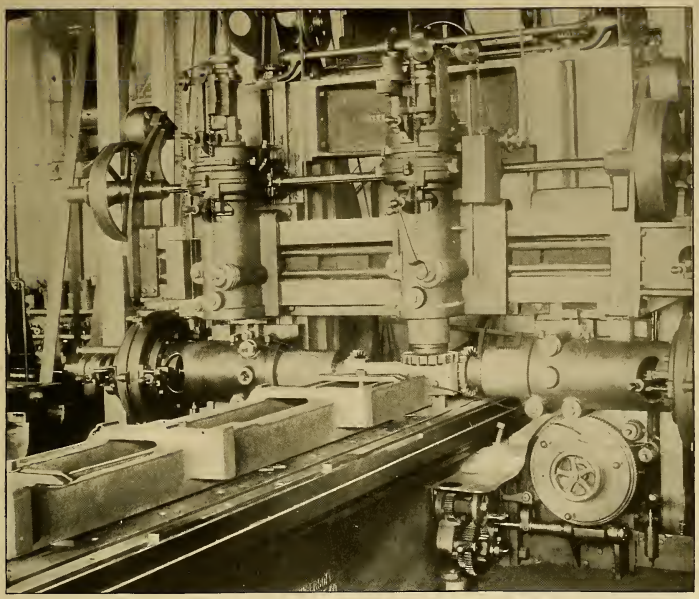


FIG. 2.—THE MILLING MACHINE SHOWN IN FIG. 1, USING THREE CUTTERS AT ONCE

himself a decided back number. In shops which he would remember as having been noted for fast cutting speeds he might find possibly the same tools working at double the former speeds, but more likely he would find them replaced by new and stronger tools,—departures from former designs, and built with a view toward keeping pace with, or anticipating, changes in conditions.

These machines are working with cutting tools made of steel that will stand higher speeds than he had been accustomed to, and are running at faster speeds and using faster feeds than he would have considered possible. Naturally, such machines are much more massive than their prototypes of five years ago. They are fitted with powerful positive feeding mechanisms and devices for changing the rate of feed to suit any particular job, instantly and without stopping the spindle. This applies particularly to lathes, boring mills, drills, and milling machines. It is the object of this article to touch only on what is being accomplished on the last mentioned tools.

Considerable educational work has been done on the part of milling machine manufacturers, first by studying carefully their own machines and determining what can be accomplished on them, and afterward by the gratuitous distribution of information based on data collected from actual practice. Some makers have been exceedingly liberal in this respect, cheerfully giving advice on milling any sort of a job, and whether it can be milled profitably, the advice often accompanied by data and illustrations showing how someone else, probably your own neighbour, is successfully milling a similar job. The result has been a better understanding on the part of foremen and superintendents of the possibilities of these machines and a consequent increase in their use, which re-

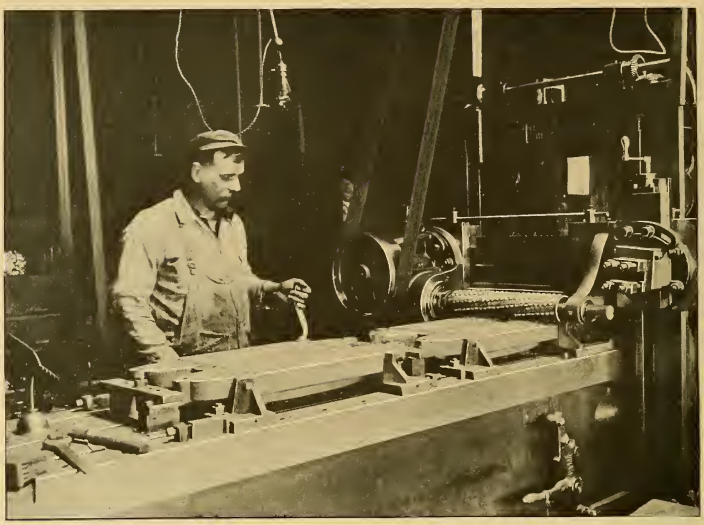


FIG. 4.—A FARWELL MILLER, MADE BY THE ADAMS CO., OF DUBUQUE, IA., U. S. A., ATTACHED TO A PLANER MADE BY THE G. A. GRAY CO., OF CINCINNATI, OHIO, SLABBING TWO MOULDING MACHINE TOPS AT ONE TIME

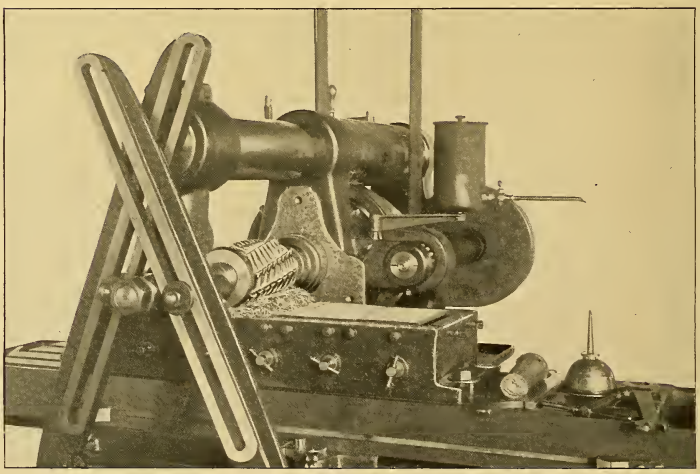


FIG. 5.—A PLAIN MILLER MADE BY THE CINCINNATI MILLING MACHINE CO., CINCINNATI, OHIO SLABBING SEVERAL THIN PIECES OF CAST IRON AT ONE TIME

dounds to the credit of the concerns who are foremost in the dissemination of knowledge on the subject, and to the prosperity of all.

The illustrations and data used in this article have been selected to show as briefly, and, at the same time, as comprehensively as possible, what can be expected from the intelligent use of the modern milling machine. Fig. 2 shows a 63-inch, four-head Ingersoll miller finishing part of a printing press, using three cutters, two on the side heads and one on the vertical head. In Fig. 3 this tool is shown in operation on housings for a machine which will be a duplicate of itself, again using three cutters, this time two on the vertical heads and one on the side head. The cutters on the vertical heads are 10 inches in diameter, and the one on the side is 20 inches in diameter; each removes about ¼ inch of stock at a table feed of 3 inches per minute. In each case we have a machine finishing, at a single traverse, three surfaces, each approximately 10 inches wide, and in less than half the time that it would take to do it on a planer, the method of chucking the work and the amount of time required to do it being about the same on either machine. And yet it is evident that the miller is not working to its full capacity on either of the above jobs, since one spindle, which might just as well be carrying a 10-inch cutter, if the work required it, is idle. Fig. 1 shows the machine complete.

In Fig. 4 we have a Farwell miller attached to a Gray planer, slabbing two moulding machine tops at one time. The cutter is of the well-known Ingersoll type. Four castings are held on the planer bed at one time; while the cutter is traversing the first pair the operator chucks the second pair, and so on, making the operation a continuous one, which would obviously be impossible when planing. Here, again, we find that the average milling time is less than half the best planing time.

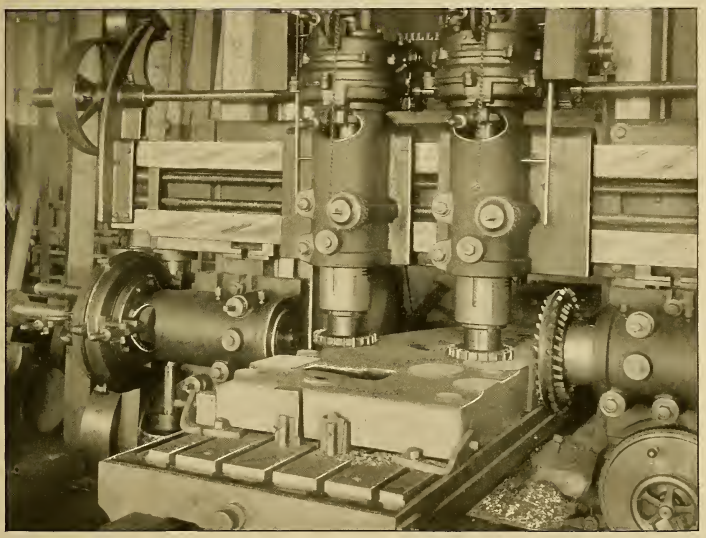


FIG. 3.—THE SAME MACHINE, AGAIN FINISHING THREE SURFACES AT ONE OPERATION, BUT WITH A DIFFERENT COMBINATION OF CUTTERS

Fig. 5 begins a series of operations performed on a different, but no less interesting, type of machine than the foregoing, and shows a plain miller slabbing cast iron pieces, taking a cut 4¼ inches wide and about 3-32 inch deep. The cutter is 4½ inches in diameter, works at a surface speed of 40 feet and a table feed of 5¾ inches per minute. The pieces are thin, and would require a special fixture to hold them on a planer, just as a special fixture is required on the miller.

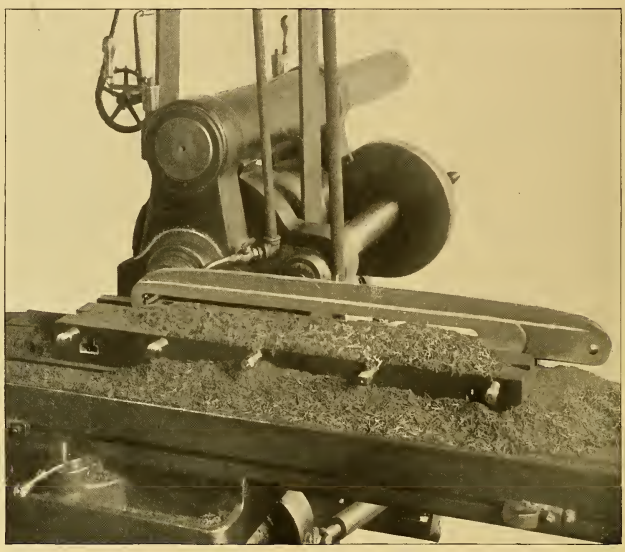


FIG. 6.—MILLING SLOTS FROM THE SOLID, STARTING WITH A SINGLE DRILLED HOLE

This same machine is shown in Fig. 6, milling slots ¾ inch wide from the solid into cast iron bars 1 inch thick at a single cut, using an end mill working at about 70 feet surface speed. About 4 inches of this slot are milled in one minute, which means that, starting from a single drilled hole, this slot, 22 inches long, is milled from the solid in five and one-half minutes. Formerly these slots were cast into the bar. They are bolt slots, and need not be accurate; but it was always necessary to spend some time "smoothing them up," and this would seem the natural way to make such pieces. To those of us who have spent much time in skillfully designing machinery so as to be able to use castings "in the rough" as much as possible, the information that the slots are milled into the above pieces, leaving a nicely finished job in less time than it used to take to "smooth up" the rough cast slots, comes as a good bit of a surprise. And yet this is only one of many instances that might be cited. One of these may be worth mentioning.

Not long ago the writer spent considerable time going over the details of some woodworking machinery, at the invitation of, and in company with, the shop superintendent, with a view to selecting parts that could be milled profitably. In the case of a large number of these parts the superintendent said, "Never mind that piece,—we use it in the rough," and he was somewhat skeptical when told that he could save money by adding finish to his patterns

and milling the pieces. After a miller had been installed for some time, and he saw the results that his own men were getting from it, he changed some patterns for "to-be-used-in-the-rough" castings, and later on took considerable pride in showing some bearing caps that he had milled "in much less time than it used to take to chip the lumps off," which had always been

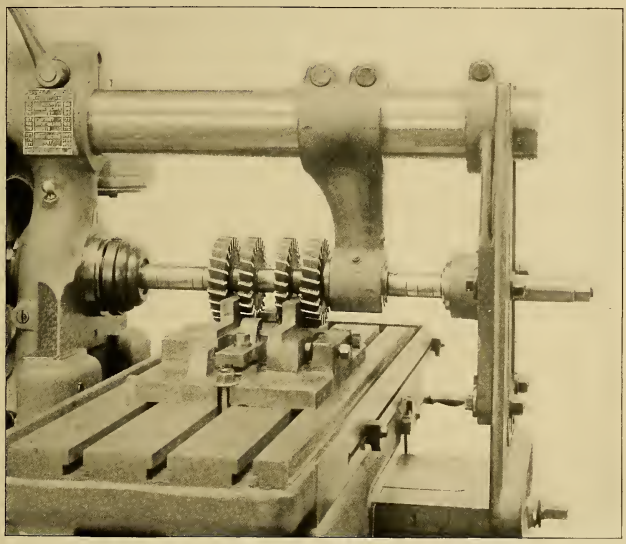


FIG. 7.—MILLING THE BOTTOM OF THE SLIDES OF A MILLING MACHINE VISE

necessary to make them lie flat on the fibre spacing strip that is placed between the babbitted bearing and its cap on this class of machinery. The caps in question were about 6 inches wide by 9 inches long, and he was milling them in lots of fifty in an hour and a half for the lot. The miller was working at a table travel of more than 10 inches per minute, which brings us to the much talked about subject of fast feeds, upon which depends the whole matter of successful milling.

Treating each tooth of the cutter as a lathe tool, and assuming a cutter with twenty teeth, if the machine is fed 0.020 inch per turn of cutter, each tooth will take a cut 0.001 inch deep, if all the teeth are exactly of the same height and the cutter runs dead true,—conditions not obtainable in actual practice.

But let us suppose that it is practicable to obtain such conditions, and that the passage of each tooth finishes 0.001 inch of linear surface. The nature of the action of a milling cutter is such that the chips are wedge-shaped, the point of the wedge being at the point where the tooth enters the metal. Obviously, then, if the cutter becomes slightly dulled, a very little spring in the arbour or some other working part of the machine permits the teeth to slide over until the resistance of the sprung parts of the machine is sufficient to force one of the teeth, always the one that is higher than the others, to enter the metal and remove a chip. The result is that all the cutting is done by a few teeth, and the edges of the teeth that refuse to cut are injured more by sliding over the surface than they would be if

the machine were fed at a faster rate so as to give each a chance to take a cut. We all know that it is not practicable to make machine tools of this sort that will not spring so much as 0.001 inch under a cut.

It is this springing of the machine and the unsatisfactory cutter action just described that is largely to blame for that great trouble with all milling machines, —the tendency to "chatter." The natural solution, then, is to increase the rate of feed. Whatever theories different mechanics may hold, the fact is that this does solve the difficulty. A cutter working at a reasonable surface speed, say 40 feet, taking a roughing cut in cast iron, will actually give better service when working at a fast feed, say ¼ inch per turn, for a cutter having ten teeth, than if worked at a feed of 1-16 inch per turn. In connection with all this we must remember that when taking a finishing cut with the peripheral teeth of a cutter the feed must necessarily be quite slow, say 0.03 inch to 0.05 inch per turn of a 20-tooth cutter, to prevent excessive unevenness on account of revolution marks. But such a cut is necessarily light, and the cutter will, therefore, keep its edge well, and may safely work at a high surface speed.

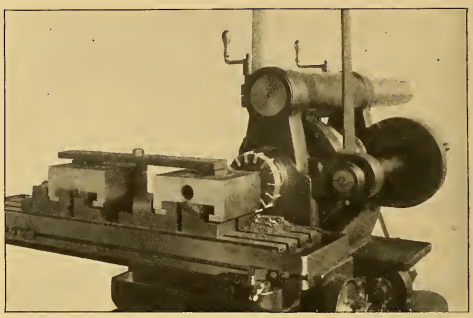


FIG. 8.—USING A FACE MILL

Generally speaking, revolution marks are not nearly so objectionable as is often supposed. Anyone can satisfy himself as to this by attempting to measure by ordinary means the height of the waves caused by the cutter. A single stroke of a scraper will remove quite serious-looking waves when the same stroke of the scraper will not remove the marks of a planer tool from a surface that has a nice "finished" appearance. This is all because of our way of looking at things. A planed surface, having a certain appearance that we have for years associated with finished work, is more or less familiar to us. Compared to it the appearance of a milled surface is very bad, while it may be actually the more nearly true surface of the two. We judge the accuracy of such surfaces by measuring them with the eye by the aid of the reflected and intercept-

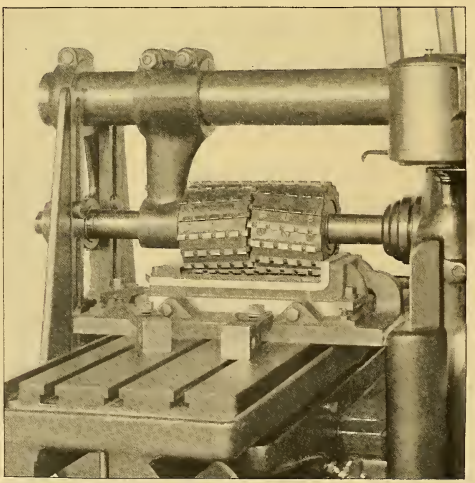


FIG. 9.—MILLING THE TOP OF A MILLING MACHINE VISE BED

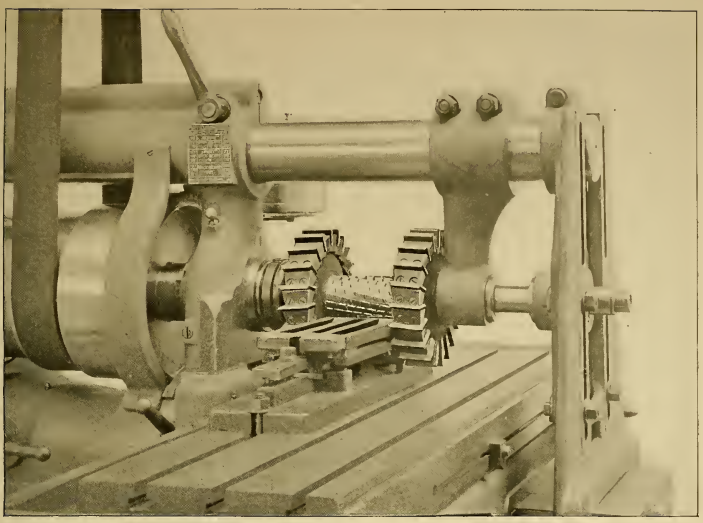


FIG. 10.—ROUGH MILLING THE BOTTOM AND BOTH SIDES OF A MILLING MACHINE VISE

ed rays of light,—the same means, by the way, by which the closest known physical measurements of surfaces are obtained.

Since the slightest depression on a polished surface can be plainly seen when the surface is held to the light, it is no wonder that we are so often deceived by the "waves" caused by a milling cutter that does its work with teeth arranged about its circumference. When milling with a face mill, as shown in Fig. 8, the rate of feed does not so seriously affect the quality of the surface produced. In the case illustrated the surface is 3⅝ inches wide, the cutter is 6 inches in diameter, and removes 3-16 inch of stock at a surface speed of 40 feet per minute and a table feed of 5¼ inches per minute. The resultant surface is smooth, and would be classed as a "good finish" in the most exacting shops.

Figs. 7, 9, 10 and 11 show a Brown & Sharpe plain miller performing the necessary operations for finishing all the surfaces on the body and slide of a milling machine vise. This is a good example of commercial milling. The pieces are practically ready for assembling when they are received from the milling machine. The rates of feed given in the accompanying data are by no means the limit of the machine, but are the fastest that are considered advisable from a commercial point of view, as faster feeds would not leave the pieces in a condition to meet the requirements for assembling the vise itself.

Fig. 9 shows milling the top of the vise bed, or that part on which the jaw slides. There are two cuts in this operation, as follows:—Roughing,—depth of cut, 3-32 inch; surface speed, 50 feet per minute; table feed, 5 inches per minute. Finishing,—depth of cut, 0.01 inch; surface speed, 50 feet per minute; table feed, 1¼ inch per minute; width of cut, 12 inches; length, 7 inches. The cutter used is an interlocked milling cutter with inserted teeth, nicked.

Fig. 7 shows milling the bottom of the vise slides. There are two cuts in this operation, as follows:—Roughing, —depth of cut, 1-16 inch; surface speed, 38 feet per minute; table feed, 4½

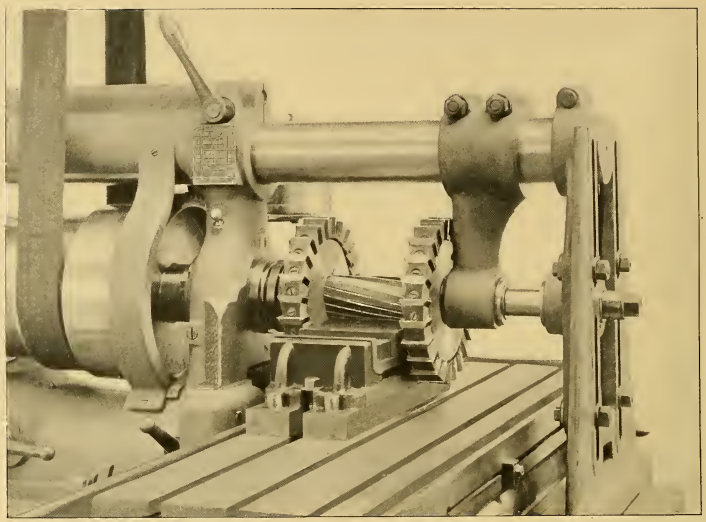


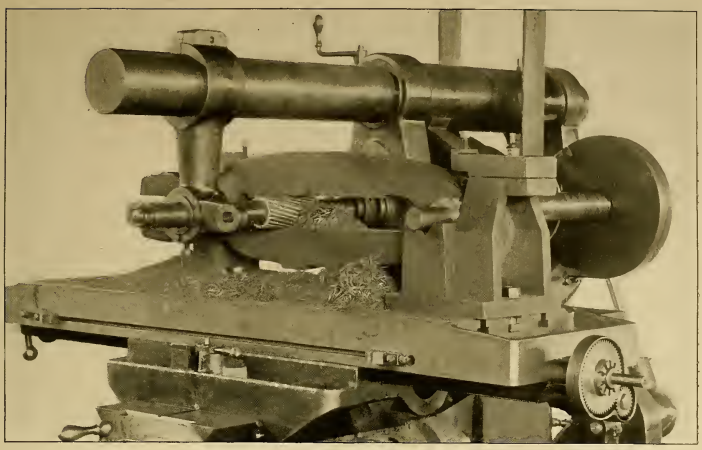
FIG. 11.—FINISHING MILLING THE TOP AND BOTH SIDES OF THE VISE

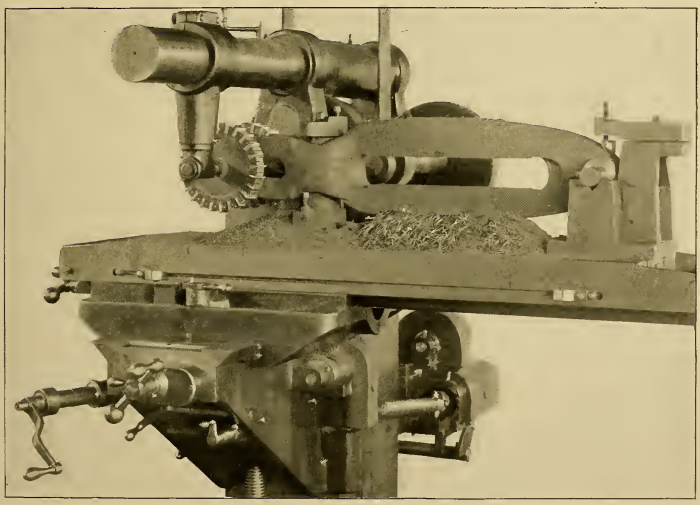
inches per minute. Finishing,—depth of cut, 0.01 inch; surface speed, 58 feet per minute; table feed, 3 inches per minute; total surface being milled, 8½ inches; length of cut 8¾ inches. There are four side milling cutters, two 6 inches in diameter, 1⅛-inch face; and two, 6 inches in diameter, ⅞-inch face. Attention might be called to one feature in connection with this operation, namely, that the cutters have sharp corners, and to insure accuracy of the finished product they must necessarily be run at a speed that will maintain the sharpness of the corners. If they were run at a higher speed, the corners would soon become rounded and impair the efficiency of the work.

Fig. 10 shows rough milling of the bottom and both sides of the vise. Depth of cut, 3-32 inch; surface speed, 45 feet per minute; table feed, 4⅜ inches per minute; total width of cut, top and two sides, 12 inches; length of cut, 19½ inches. Cutters,—two inserted tooth side milling cutters, 12 inches in diameter; one milling cutter with nicked teeth, 3 inches in diameter.

Fig. 11 illustrates finishing milling of the top and both sides of the vise. Depth of cut, 0.01 inch; surface speed, 87 feet per minute; table feed, 5⅞ inches per minute; total width of cut, top and two sides, 15¼ inches. Two side milling cutters with inserted teeth, 12 inches in diameter; one milling cutter with spiral teeth, 3 inches in diameter. This leaves the pieces in a finished condition, ready for assembling, and requiring very little or no "fitting."

Another application of the milling machine for finishing all over parts entering into machine tool construction is shown in Figs. 12 and 13, which illustrate a plain miller taking two of the twelve cuts required to mill all the finished surfaces of a rocker arm for a 24-inch shaper. Referring to Fig. 12, the cutter is 2¾ inches in diameter, takes a cut 1-16 inch deep at the top and bottom of the slot at the same time, feeding 3 inches per minute. The lugs at the top and bottom and the short slot at the end are finished in the same way with this same cutter. It has a face more than twice the width of the cut;





FIGS 12 AND 13.—MILLING A ROCKER ARM FOR A SHAPING MACHINE ON A CINCINNATI MILLER

one end is used for roughing; for finishing, the work is moved out to the other end of the cutter which is reserved for this part of the work, and consequently is always in place, ready for use. In this way one cutter is made to serve both for roughing and for finishing. The two sides of the piece are finished with a 9½-inch diameter face mill, fastened to the spindle of the machine.

Fig. 13 shows a gang of cutters 8½

inches in diameter finishing the fork part. All the surfaces are finished at one setting of the piece, except the side farthest from the machine and the lug on the bottom, for which it is reversed in the fixture. This is considered not only a good example of what can be accomplished on a miller, but also proves that elaborate fixtures for holding the work are not necessary. The actual time charged for finishing the rocker arm all over is two and one-quarter hours, against the best previous planer time o fourteen and one-half hours.

Another class of miller that is coming into very general use has its spindle in a vertical position, and is intended largely for face milling, for which it has an advantage in chucking the pieces to be milled, in that it is assisted by gravitation, and the thrust of the cutter is always toward the table, there being an entire absence of the lifting effect which results from a cutter used for slabbing.

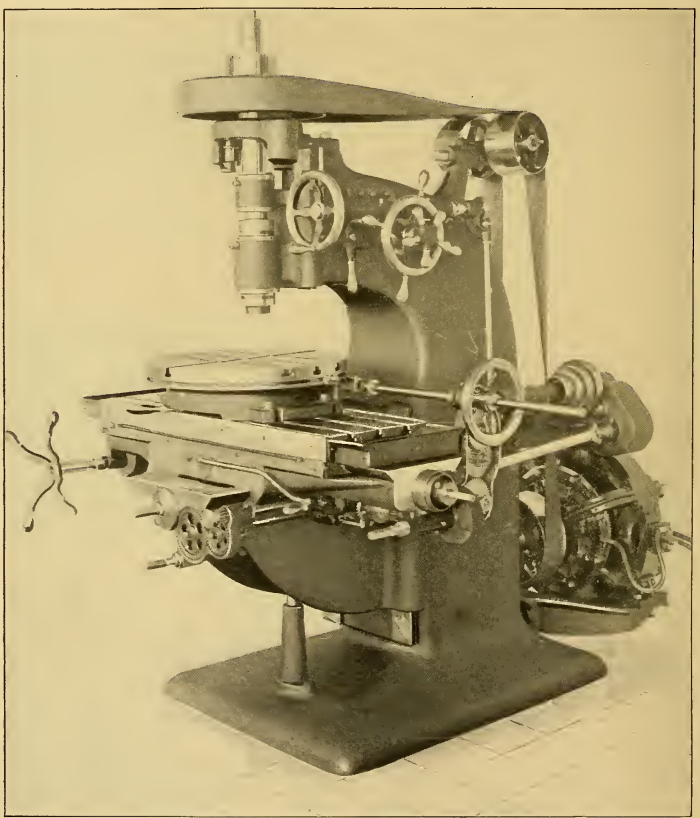


FIG. 14.—A HEAVY VERTICAL-SPINDLE MILLING MACHINE WITH AUXILIARY ROTARY TABLE AND ELECTRIC MOTOR DRIVE. MADE BY THE BECKER-BRAINARD MILLING MACHINE COMPANY, HYDE PARK, MASS., U. S. A.

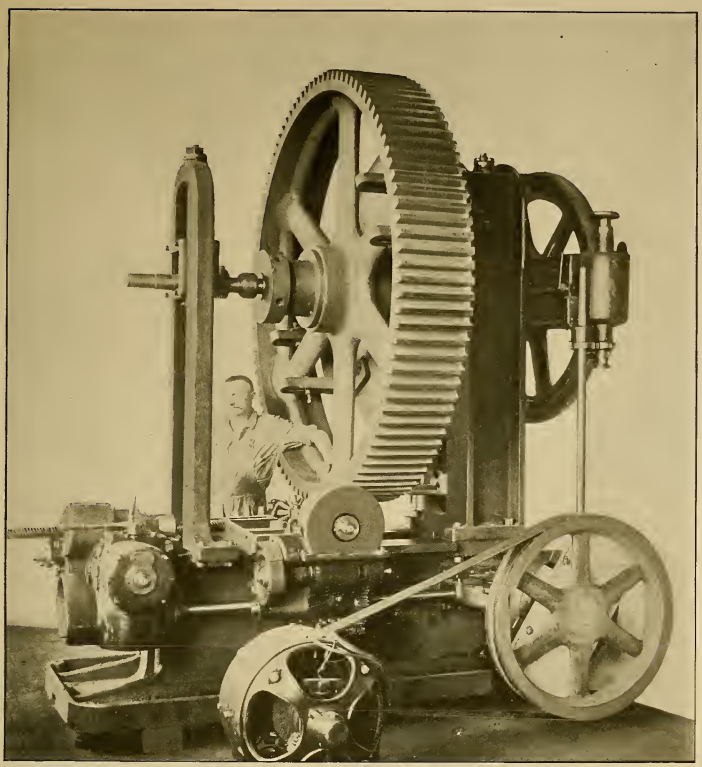


FIG. 15.—A NEW TYPE GEAR-CUTTING MACHINE, MADE BY MESSRS. GOULD & EBERHARDT, NEWARK, N. J., U. S. A.

The machine shown in Fig. 14 is made by the Becker-Brainard Milling Machine Company, and may justly be considered as representative of its class. The following illustrations serve to demonstrate what can be accomplished with it. In Fig. 16 it is face-milling a surface 12 inches wide with an economy of three to one over planing, and the scraping necessary to give the desired finish for a bearing is reduced in like proportion, for the reasons given in another part of this article. In Fig. 17 it is finishing the angular bearing of a slide in fifty minutes that used to take three hours to plane.

Fig. 15 shows Eberhardt's 84″ × 16″ new type gear-cutting machine cutting one of a lot of several large cast-iron gears, 100 teeth, 1¼ diametrical pitch, 81.6 inches outside diameter, 13 inches face. The motor-drive arrangement was rigged up temporarily on account of the weight of the gears making it necessary to put the gear-cutting machine in a special part of the shop where there was no line shafting. This explanation is made in justice to the builders, as we would not wish to convey the idea that this is the way they equip their machines when they apply a direct-connected electric motor drive.

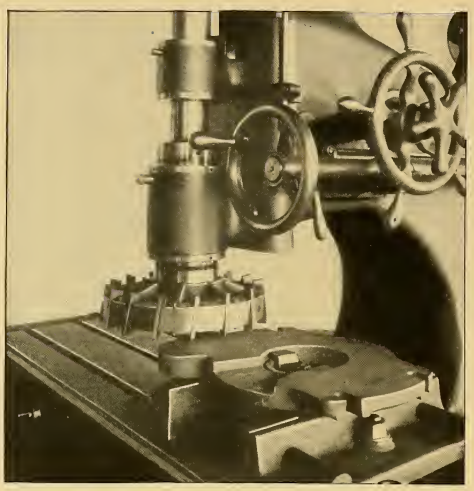


FIG. 16.—FACE MILLING ON A BECKER VERTICAL MILLER

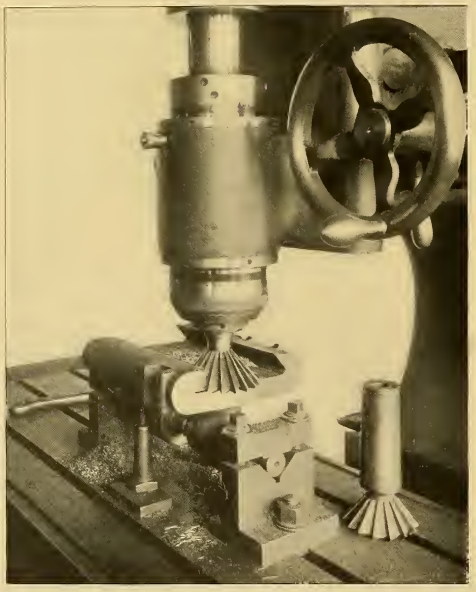


FIG. 17.—FINISHING THE ANGULAR BEARING OF A SLIDE

The setting time was five hours, and the actual cutting time thirty-two hours, the cutting being done in three cuts. The first cut was a saw tooth cut; the second cut blocked out the gear to within about 1-16 inch of the finished depth of the tooth; and on the third time around with the cutter it was finished to the full depth. The first blocking cut required sixteen hours; the second cut, nine; and the third, or finishing, cut, seven hours. This is the approximate time required on each one of the gears, although the first gear required more because of getting the machine into shape. The length of time required on this class of work depends a great deal upon the accuracy required. The gears illustrated are of "ordinary accuracy."

The machine shown in Fig. 18 possesses more than ordinary interest in that it is expected to revolutionise thread cutting and to do away with the use of the engine lathe for that purpose. This means that the process of milling is about to replace the time-honoured process of turning, to a certain extent at least, as it has already superseded shaping and planing on a variety of work. The machine illustrated is made by the Pratt & Whitney Company, and will mill the threads on work 6 inches in diameter and 80 inches long. It is designed for the manufacture of precision screws, worms, lead screws, and spiral gears, for all cases requiring extreme accuracy, as in the best grade of machine tools. It is also intended for coarser

work, such as rock drill feed screws, thrust screws for friction hoisting drums, etc., which do not require a high degree of accuracy and finish, but on which economy of manufacture is of prime importance.

Ordinary machine tool lead screws can be cut to the full depth of cut at one operation, at the rate of 3½ to 4½ inches per minute (measured around the screw) within limits of error of 0.001 inch per foot of finished screw. Similar screws not requiring precision can be cut at a much faster rate. This means that from a bar 1¼ inches in diameter a 4-pitch lead screw can be finished complete with an error of less than 0.001 inch per foot of length at the rate of 1¼ feet per hour. The heating and consequent expansion of the work which result in inaccuracy in lathe-chased

No. 1—
Machine Steel Worm
4 in. diameter x 4 in. length of thread
1½ in. lead triple
Depth of tooth .3382 in.
Thickness of tooth at pitch line ¼ in.
Cutter 3 in. in diameter
65 revolutions per minute of cutter
One revolution of blank in 3.43 minutes
51.02 feet per minute periphery speed of cutter
3.66 in. per minute periphery speed of worm blank
.056 in. feed per revolution of cutter
Two cuts, roughing and finishing
Actual milling time 55 minutes for both cuts.

Estimated time to cut the thread on this worm on a lathe, four hours.

No. 2—
Machine Steel Worm, 0.50 carbon
3 in. diameter x 3 in. length of thread
⅛ in. lead single
Depth of tooth .3382
Thickness of tooth at pitch line ¼ in.
Cutter 3 in. in diameter.
65 revolutions per minute of cutter
One revolution of blank in 3.14 minutes
51.02 feet per minute periphery speed of cutter
3 in. per minute periphery speed of worm blank
.046 in. feed per revolution of cutter
Two cuts, roughing and finishing
Actual milling time 38 92 minutes for both cuts.

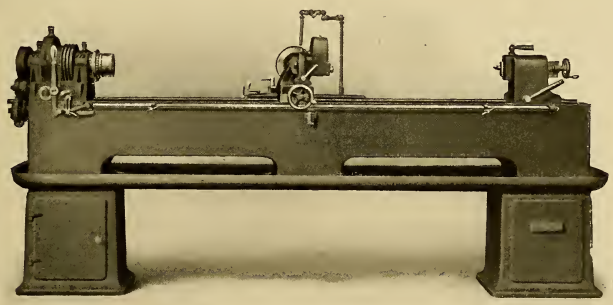


FIG. 18.—A THREAD MILLING MACHINE, BUILT BY THE PRATT & WHITNEY COMPANY, HARTFORD, CONN., U. S. A.

screws are entirely absent when the threads are milled.

Fig. 20 shows a rear view of a worm milling machine made by the Cleveland Automatic Machine Company. The class of work for which this machine is adapted is shown in Fig. 21, which represents worms actually milled on this machine.

An idea of the efficiency of the machine for such work may be obtained from the following data:—

Estimated time to cut the thread on this worm on a lathe, two and one-half hours.

No. 3—
Cast Iron Worm
4 in. diameter x 4½ in. length of thread
1 in. lead single
Depth of tooth .6763 in
Thickness of tooth at pitch line ⅛ in.
Cutter 3½ in. in diameter
80 revolutions per minute of cutter
One revolution of blank in 3½ minutes
73.26 feet per minute periphery speed of cutter
3.59 in. per minute periphery speed of worm blank
.044 in. feed per revolution of cutter
Two cuts, roughing and finishing
Actual milling time 35 minutes for both cuts.

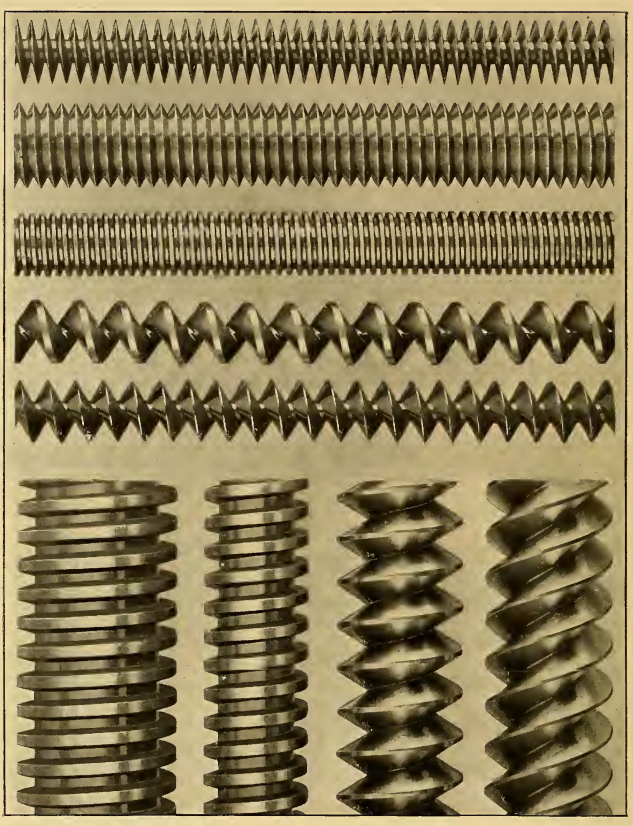


FIG. 19.—SOME OF THE WORK DONE ON THE PRATT & WHITNEY THREAD MILLING MACHINE

Estimated time to cut the thread on this worm on a lathe, three hours.

No. 4—
Machine Steel Worm
2½ in. diameter x 2 in. length of thread
⅜ in. lead double
Depth of tooth .2254 in
Thickness of tooth at pitch line 1/16 in.
Cutter 3 in. in diameter
90 revolutions per minute of cutter
One revolution of blank in 2.09 minutes
70.65 feet per minute periphery speed of cutter
3.75 in. per minute periphery speep of worm blank
0.41 in. feed per revolution of cutter
Two cuts, roughing and finishing
Actual milling time 25.24 minutes for both cuts.

Estimated time to cut the thread on this worm on a lathe, two hours.

No. 5—
Machine Steel Worm
3⅜ in. diameter x 4 in. length of thread
1½ in. lead double
Depth of tooth .5073 in.
Thickness of tooth at pitch line ⅜ in.
Cutter 3½ in. in diameter
60 revolutions per minute of cutter
One revolution of blank in 4.71 minutes
54.95 feet per minute periphery speed of cutter
2.5 in. per minute periphery speed of worm blank
0.41 in. feed per revolution of cutter
Two cuts, roughing and finishing
Actual milling time 42.4 minutes for both cuts

Estimated time to cut the thread on this worm on a lathe, three and one half hours.

In considering the time on the lathe against the time on a milling machine

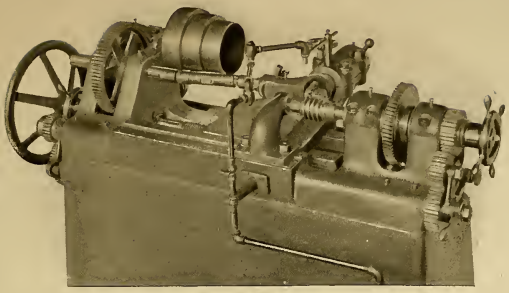


FIG. 20.—A WORM MILLING MACHINE MADE BY THE CLEVELAND AUTOMATIC MACHINE CO., CLEVELAND, OHIO, U. S. A.

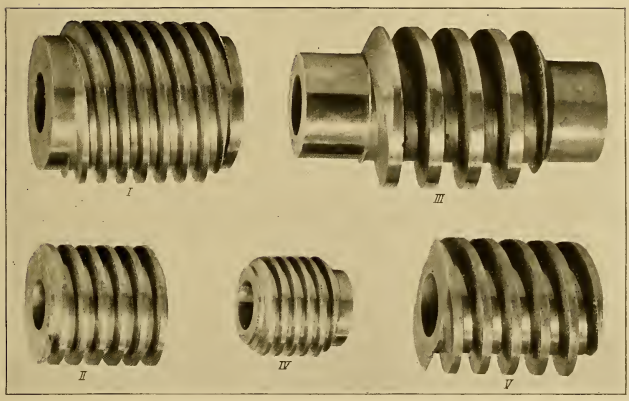


FIG. 21.—WORMS MILLED ON THE MACHINE SHOWN IN FIG. 20

and comparing the rates of wages paid for the two different methods of cutting these worms, it is very easy to see the vast saving when the work is done on the milling machine.

Let us take, for instance, Worm No. 1,—estimated time on lathe four hours and wages of workman $2.75 per day, which makes a total cost for cutting this work, $1.10. This same worm can be milled in fifty-five minutes. The man operating this machine could, and should, be doing something else besides, so that not more than $1 per day of his wages should be charged to the machine. Calling the total time of milling one hour, we have the cost of milling the worm,—10 cents. against $1.10 for cutting the thread on a lathe.

The makers of this machine consider this a fair and just estimate, because in operating these machines in their own factory the man also runs a hobbing machine and a gear cutter, the man's wages being $2.75 per day.

The use of this machine, as in the case of the one previously described, has the advantage not only of a remarkable saving in cost over lathe work, but it also turns out a product of much higher quality than is practicable to obtain on a lathe.

FAST COLLIERS FOR THE BRITISH NAVY

By E. H. T. d'Eyncourt, M. Inst. N. A.

NOW that so much is being thought of and said about the needs of the British Navy and Army, the time seems not inappropriate to bring to notice a matter which, as far as can be gathered, has been, to some extent, lost sight of, but which appears to be one of the very first importance. It is the proposed construction for the Navy of some fast colliers, specially designed for the purpose of attending upon the various squadrons and supplying them quickly with coal, wherever they may be.

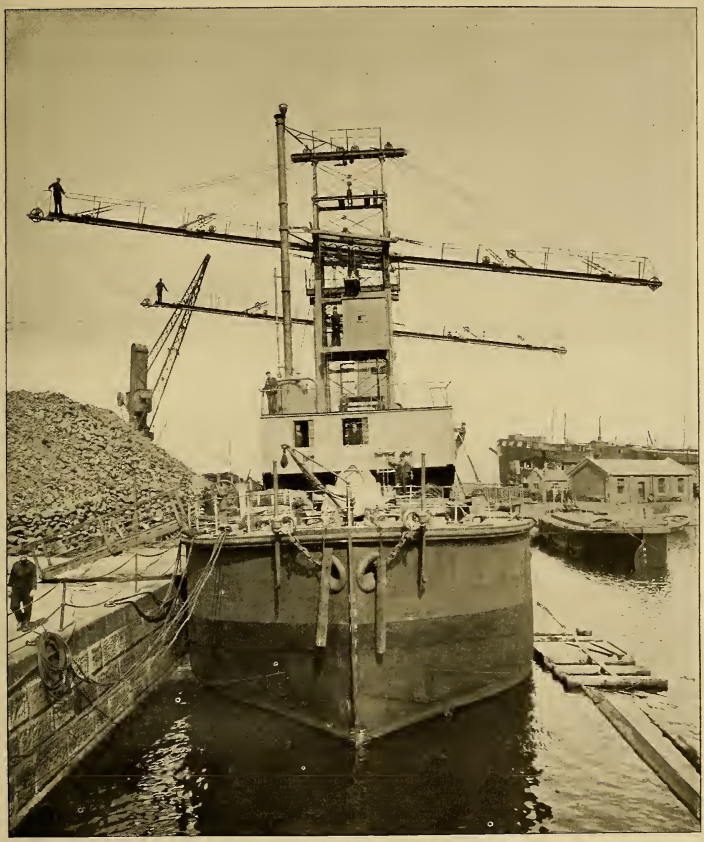
The government has, no doubt, considered the question of building some vessels of that kind, and some barges have actually been turned out which can be towed about, and have all the necessary appliances for dealing expeditiously with a cargo of coal. These barges carry about 1000 tons. Some much larger vessels of a similar character, but with a capacity of about 10,000 tons of coal, are under consideration; but these vessels, like the smaller barges, or coal "haulabouts," as they are termed, have no means of propelling themselves, and can be moved about only very slowly by towing.

Both the above-named types of vessels will doubtless prove exceedingly useful, and will help to hasten the process of coaling warships in the close neighbourhood of the coaling station or depot to which they belong. But though in this way they may prove of great service, these coal haulabouts lack that most vital necessity in time of war, —mobility.

It appears essential, therefore, that the Navy should possess a sufficient number of vessels with all modern appliances, such as Temperley transporters, for quickly dealing with coal, both in harbour when taking it on board, and at sea, when discharging into warships alongside; and that these vessels should also be able to keep up with the ships, —not, perhaps, with the fastest cruisers at full speed (as to accomplish this and to carry a good cargo of coal is well-nigh impossible, except by going to very large and costly ships), but certainly to keep up with the most modern armourclads,—in other words, to be capable of maintaining a sea speed of 17 knots, and to do 18 knots in an emergency.

If this can be achieved, a great deal will have been done towards increasing the efficiency of the Navy; and we shall find that it can be done at a cost which is small when set against the immense advantages which will be gained. To take a military parallel, it has surely been proved again and again in the Boer war that mobility was the most important of all qualities in an army. This being accepted, it needs no elaborate proof to show that mobility is doubly important for a fleet. However, to pursue the comparison further, let us consider the relative strengths of two armies of equal numerical value, one of which has to return to its base at frequent intervals for supplies, while the other has its supplies continually brought on close behind, keeping pace with the advance of the army. To a great extent the former case approximates to the condition of a modern fleet, as far as coal is concerned. Which of the two is superior scarcely requires pointing out.

Napoleon said that an army "moves on its belly"; it is equally true to say that a fleet moves with its coal. It must not be forgotten that a modern warship, when out of fuel, is far more helpless than one of the old-time sailing vessels. The high rates of speed now attained by warships are no doubt of extreme value; but the ability to keep the sea for a long period at a good rate of speed, or, as it



A COAL "HAULABOUT" AT PORTSMOUTH WITH A CAPACITY OF 1000 TONS. THE COAL IS HANDLED BY TWO TRAVELLING CRANES AND TEMPERLEY TRANSPORTERS. THE CRANES MOVE ALONG RAILS LAID ON EITHER SIDE OF THE HATCH. THE ILLUSTRATION SHOWS THE TYPE OF FLOATING COAL DEPOT WHICH THE BRITISH ADMIRALTY HAS DECIDED TO BUILD. THE VESSEL, AS ITS NAME IMPLIES, CAN BE MOVED FROM PLACE TO PLACE ONLY BY TOWING, AND IS NOT INTENDED IN ANY SENSE TO SUPPLY THE PLACE OF THE SELF-PROPELLING COLLIER OF WHICH MR. D'EYNCOURT WRITES

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is usually termed, the radius of action, is of equal importance.

It has been customary to give the radius of action of naval vessels at a very low speed, usually 10 knots. This may be very well on paper, and is no doubt good enough in times of peace, when such a slow speed has the great merit of economy; but it would never do in war time to crawl about at 10 knots if a higher rate could possibly be attained and maintained with safety, and without too great a risk of being left without coal at a distance from the nearest coaling station. Without coal ships in attendance, when the coal is nearly used up, or perhaps only half used up, in the case of the base being distant, the fleet must return to base for coaling; and without fast colliers such as are proposed, how often would the coaling ship be close at hand? We, therefore, may find the fleet in the condition of the inefficient army which has to return to its base for supplies every few days.

The fleet which can keep at sea for a long period will have an incalculable advantage over the one which cannot do so and has to return frequently to coal. Warships must necessarily return now and then for docking and cleaning and repairs, and also for provisions and water, unless these can be supplied them in the same way as coal; but that is no reason why the far more frequent return for coal should not be avoided if possible. It requires no great stretch of imagination to picture a naval campaign in which the result ultimately depended on the fact of one of the opposing fleets being able to outlast the enemy in fuel.

Granted the necessity for fast coaling vessels, it may be argued that many of the faster liners would do for the purpose; but this is not the case, for, though no doubt they would be useful, they would not be the best means procurable for the object in view, for the simple reason that they have not been designed and built with this one object. They could not carry the maximum amount of coal possible, nor have they the appliances for dealing with coal in the most expeditious manner.

Then, again, the number of ships of the mercantile marine having a speed of 18 knots is limited, and these vessels would probably be required in time of war for other purposes, such as bringing food supplies from abroad, transporting troops, and possibly helping as scouts. The Boer war never brought home to the public mind the necessity of having fast transports and provision ships with speed enough to elude the enemy's cruisers, because, being purely a military war, there were no cruisers to elude, and, accordingly, a great number of quite slow ships were requisitioned by the Admiralty and did excellent service. Many of these would doubtless have fallen an easy prey to a foe possessed of a navy.

No more need, therefore, be said here on the point that in the case of Great Britain being involved in a big war her fast merchant ships will all be needed for the various purposes alluded to. The slower vessels, which usually carry coal to the various coaling stations, will be more busily engaged than ever in keeping pace with the increased demand for fuel at those stations, and will be practically useless to attend on the various squadrons on account of their slow steaming qualities. The necessity thus remains for fast colliers.

The number of such vessels that would be required must be decided by those who make the organising of naval campaigns their special care and study. However, eight such vessels might first be tried,—that is, two to each of the four most important squadrons. They should be located in pairs or larger groups at the principal coaling stations, so that whilst one of each pair is taking in coal in port, the other may be giving coal to the vessels of the squadron at a distance. They should be able to steam 17 knots easily and continuously, and 18 knots in case of emergency, and in order to maintain a high speed in rough weather and carry a large quantity of coal, say 10,000 tons, besides coal for their own use, the vessels must be of considerable size.

These various requirements could be met by vessels of approximately the following dimensions:—Length, 550 feet;

beam, 66 feet; draught of water, 27 feet 6 inches with 10,000 tons, so as to be able to go through the Suez Canal with full coal. On a greater draught, when there was no question of passing through the canal, a greater quantity of coal could be carried. The amount would, however, be naturally limited by the cubic capacity of the holds.

The horse-power necessary for 17 knots at sea would be about 11,000. The machinery would be of the most economical type, with quadruple expansion engines and cylindrical boilers with Howden's forced draught. They would consume less than one and one-half pounds of coal per I. H. P. per hour, so that at full speed the collier could go 1000 miles from the coaling station and back on 800 tons of coal. Carrying 10,000 tons of coal to the fleet would be enough to coal five of the largest battleships or cruisers fully, or ten to the extent of half-full bunkers, or a larger number of smaller warships.

Any one of the large cruisers or armour-clads would take from four to five days to go the 2000 miles, would use at least 1000 tons of coal, and would have been steaming hard all the time, arriving with dirty boilers, a tired complement of stokers, and a great part of her coal already burnt. Possibly 1000 miles from a coaling station is a long way to assume; but the same thing is true for a shorter distance, only not to such a marked extent.

The coal for the colliers' own use could be carried in wing bunkers, so disposed as to give good protection to the engines and boilers as long as the coal lasted. In ordinary peace time the colliers could be used with economy for taking coal to the coaling stations, and at the naval manœuvres they could attend on the fleets as in war time. They would be made as little conspicuous as possible, so as not to attract the attention of the enemy.

The cost of each of these colliers, fully equipped with Temperley transporters and all the necessaries for quick coaling, would be about £270,000, so that four or five such vessels could be had for the cost of one first-class armour-clad or cruiser, and four could be kept in commission for about the cost of keeping an armour-clad. In time of war each would be an asset equal to several additional warships, as they would enable so many warships to remain at sea, saving them the time of going to and fro for coal, and giving them time to clean their boilers and do minor repairs to the engines, besides resting the whole crew, officers and men.

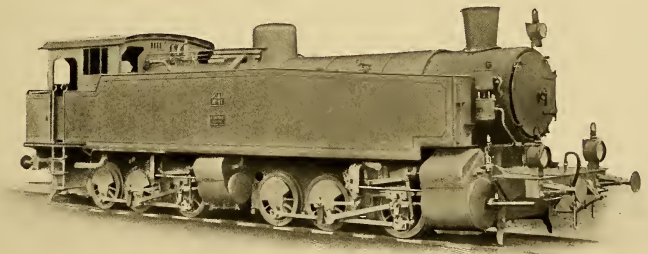
It would, no doubt, be possible to make such colliers suitable for carrying troops, fresh water and consumable stores, provisions, etc., other than coal; but to attempt this would, to some extent, spoil them as colliers, and such duties could well be carried on by other merchant vessels, especially as the warships would probably not require these other commodities nearly so frequently as coal. It would, therefore, be a mistake to reduce the efficiency of the colliers in the least degree by trying to fit them for other purposes as well.

Current Topics

THE multiple steam pipe is again being offered for service, a London firm, Messrs. W. & G. Drummond, being interested in exploiting its merits. These are primarily that it reduces the risks attending the use of very large steam pipes, especially copper ones, on the same principle that a boiler made up of a large number of small-diameter water-tubes is safer than a boiler consisting of one large cylindrical shell. There are other advantages when the multiple pipe is used in place of the ordinary single steam pipe, in a locomotive smoke-box, for example, to carry steam from the boiler to the cylinders, such as the greater pipe surface exposed to the hot gases, leading to drier, and possibly even superheated, steam. Mention of the multiple steam pipe was first made about a dozen years ago, as it is now recalled, and a few specimens of it were at that time in service; but whatever its advantages, its career does not seem to have been a prosperous one. Messrs. Drummond's pipe appears to be in all essentials like that one of earlier date, except, possibly, in so far as this latter was built up of copper pipes, while the elements of the former are steel. In both cases, however, the pipe ends enter into flange heads which hold the pipes together in bundles, so to speak. The Drummond pipe is said to have been in use on some of the locomotives of the London & South-Western Railway for several months past and with good results.

REFERRING to the article on the large ten-wheel tank locomotive on the Great Eastern Railway, which Mr. James Holden, the locomotive superintendent of that line, contributed to the May number of this magazine, Mr. A. Borsig, the well-known German locomotive builder, of Tegel, near Berlin, has favoured us with a photograph and the appended particulars of one of several still heavier and more powerful tank engines turned out by him last year for the Central de Aragon Railway, in Spain, and thus entitled to the distinction of being the most powerful engines of their class in the world. They were designed for hauling heavy goods trains up steep gradients, combined with sharp curves, and the conditions were such that the whole adhesion weight of the engine had to be carried on six axles. The four-cylinder compound articulated system was, therefore, adopted, the experience previously gained by the Borsig Works

with similar, although lighter, engines on other railways being so favourable as to point to the fact that the best way of complying with the requirements would be found in this type. The high-pressure cylinders are 18½ inches in diameter, and the low pressure cylinders 28 inches, the stroke of all four cylinders being 23⅝ inches. The diameter of the driving wheels is 43 inches. The total heating surface amounts to 2600 square feet, and the grate surface to 46½ square feet. The boiler pressure carried is 175 pounds, and the service weight of each locomotive complete is 108 tons. The coal capacity is 4 tons, and the water carried in the tanks amounts to 4450 gallons. The high-pressure cylinders which drive the three rear pairs of wheels are fixed on the main frame which carries the boiler so that there are no flexible steam pipes under boiler pressure. The low-pressure cylinders drive the three front pairs of wheels, which are carried by a separate frame, hinged to the main frame in the plane of the high-pressure cylinders, thus allowing the engine to take sharp curves easily; in fact, it may be compared in this respect to two six-coupled engines under one boiler. The exhaust from the high to the low-pressure cylinders is carried through pipes with stuffing boxes to permit of the necessary radial motion; but as the pressure here is comparatively low,—from 45 to 60 pounds,—there is no difficulty in keeping these steam-tight. In order to equally distribute the weight of the boiler and tanks, and insure sufficient adhesion for the front group of wheels, part of the weight of the boiler and tanks is carried by the front frame. Several hundreds of engines of this class are in service on different lines and are giving great satisfaction. The particular engines here considered were built for the Spanish, or 5-foot 6-inch, gauge, which has advantages for such heavy locomotives, allowing the designer more room.



A FOUR-CYLINDER COMPOUND TANK LOCOMOTIVE BUILT BY A. BORSIG, TEGEL, NEAR BERLIN, GERMANY, THE MOST POWERFUL LOCOMOTIVE OF ITS KIND IN THE WORLD

At the time of the great engineering trades strike in Great Britain in 1897 and 1898 a good deal was heard of what were known as demarcation disputes. These were disputes among the members of the various trade unions themselves as to which of them should handle certain kinds of work. No grievance against the employer was involved in the matter, but simply the jealousies among the men of different unions. Still, the result in point of time and money losses to the employer was quite as bad as if he had been one of the direct factors in the disturbance. A good illustration of the nature of these disputes is furnished by one which occurred between the Boilermakers' and the Engineers' Unions, both unions claiming for their men certain portions of the work of making Belleville water-tube boilers. The one union claimed that each tube was a boiler, and that, therefore, the fit-

ting belonged to the boilermakers. The other union claimed that a water-tube boiler was not a boiler until all the tubes were fitted together, and that, therefore, the work of fitting was the work of an engineer fitter. Long and furious was the contest waged over this question, and though the Engineers' Union abided by the decision which, after many months, awarded the work to the boilermakers, a breach had been created between the two unions which may not have healed to this day.

THERE is a long list of disputes of similar kind in British trades union history; but the demarcation trouble must not, therefore, be considered a peculiarly British institution. In the American building trades, for example, in which the strike incubus has dominated for months past, the demarcation trouble has cropped up in many forms. A strike at one large architectural iron works, as a result of which several hundred men were thrown out of employment, originated with the putting up of some ornamental iron work above the door of a building then in course of erection. There had been a rule in the unions by which the structural iron workers put up the standards and the architectural iron workers did the ornamental work. In this case the work was done in a hurry, but strictly in accordance with the canons of the unions. When it was finished a walking delegate of one of the unions came around. He jumped at the conclusion that one set of men did the whole work and gave a whistle, whereupon all the iron workers went on strike, tying up all the work on the building. It took the iron works people two weeks to find out what the strike was about. The representatives of the firm then called the walking delegate before them and explained the circumstances to him. He acknowledged that he had made a mistake, but declined, nevertheless, to let the men go back to their work unless they got "waiting time," which meant pay for the period during which they had been on strike. The firm refused to do this, and the work was held up until finally a compromise was effected.

ANOTHER interesting case was referred to as follows by a prominent contractor:—"On one of my buildings on one Friday or Saturday evening I was getting ready to put matters in shape so as to cement the floors on Monday. I wanted to lay about 25 or 30 feet of concrete so as to have it set by Monday. The masons' labourers, who usually do this work, were busy. I had some excavators and got them to do it, and it took them about an hour. A walking delegate came along and gave a whistle, which signified that a strike was declared, and all the people went out on strike. It cost $75 to settle that strike." Another contractor said he had got into trouble once or twice through the question of jurisdiction of work between the roofers and the sheet metal workers. The roofers claim the work when it is flat work, that is, laying tin plates flat on a roof, and the sheet metal workers claim the work when it is upright work. "There was a small bulkhead, as we call it," he said, "to be erected on the top of a house, which is a little wooden affair covered with tin, inside of which is the stairway leading to the roof. I happened to have roofers at work, and I got them to do it. Next day a walking delegate came around and ordered a strike. This strike lasted a long time and affected every trade in the building. The bricklayers and electrical workers," he continued, "have for some time been disputing as to which of them should make a hole in the wall in new buildings to admit electrical wires. The bricklayers say that as they lay the brick they ought to make the hole in the wall; but the electrical workers say that as they put the wires in through the hole, therefore they should make the hole. There is a strike of electrical workers on now in one building because the bricklayers made this hole."

BUT there are still other instances. In one of these the trouble was between

the sheet metal workers and the glaziers. In a certain building where the window sashes were of metal the sheet metal workers claimed the right to do the glazing, but would not assume any responsibility for breakage of glass. The contractor, therefore, had the work done by the glaziers, with the result that the sheet metal workers went on strike. They became ashamed, however, and went back to work after a short time. According to another contractor's account, he wanted a temporary pipe in a building on each floor so that the plasterers who were at work could get water on each floor. He told the elevator man to put up the pipe or to get the hoisting man to do it. This at once threatened to bring on a plumbers' strike. Offering to let the plumbers do the work, however, did not mend matters, since by that time the steam fitters were on hand with their claim to the job. They were left to fight it out among themselves, and in some way reached an agreement.

In connection with the vigorous efforts which are being made in Germany and France towards developing the use of alcohol for heating and power purposes, as evidenced by earlier references in these pages, to the alcohol appliance exhibitions at Berlin, for example, it is worth noting that European enterprise in this direction has recently extended to South American fields. Thus we find a consular report on an "exposition of alcohol appliances for industrial purposes," held at Callao, Peru, a short time ago, the object of the exposition, like that of its German forerunners, being to create a new demand for alcohol, so that, as it has been explained, the greater consumption of this article, when applied to industrial purposes, would form a new source of revenue for the owners of sugar cane estates and thus make up for the decrease in value of cane sugar. The bulk of the alcohol exhibits was German; in fact, everything was German, if we except the three or four French exhibits, and one British and one American kerosene engine, which last two must have seemed to be somewhat out of their proper element there. But they appear to have shown that the kerosene engine is still cheaper to operate in Peru than the alcohol motor.

In the remarks in these columns quite recently relative to the lifting power of magnets allusion was made to the fact that one of the uses to which the lifting power of the magnet is put is that of withdrawing small pieces of iron from the human eye. It is possible that some readers may have thought this application was more fanciful than real; but quite recently Dr. C. S. Bull has reported the case of a man who was struck in the eye by a flying piece of steel, which perforated the cornea, iris, and lens, and entered the vitreous body which became filled with blood. Dr. Bull decided to make an attempt to extract the metal by means of a powerful magnet. After bringing the magnet almost into contact with the eye, a piece of steel about 0.156 inch long and 0.136 inch wide was drawn out of the eye and adhered to the magnet. In ten days the man was discharged with vision about two-thirds normal.

Through the courtesy of Mr. D. Drummond, of the London & South-Western Railway, we have been enabled to reproduce on the next page a photograph of one of two steam-driven motor coaches, designed and built by Mr. Drummond, and intended to run between Fratton and Havant as joint stock of the London & South-Western and London, Brighton & South Coast railways. If found successful there, it is intended to employ this form of coach over a much wider range of service. Indeed, Mr. Drummond proposes, amongst other things, to use it to solve the suburban traffic difficulty which Mr. Holden is facing in quite another way on the Great Eastern Railway as told

A STEAM MOTOR COACH FOR SUBURBAN RAILWAY TRAFFIC

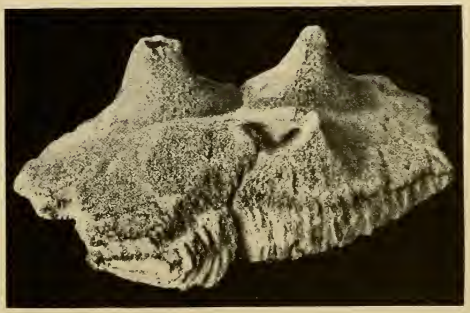
in his account in the May number of this magazine of the large tank locomotive which he built for that service. It is Mr. Drummond's idea to work his heavy morning and evening traffic with long trains and heavy engines. For the mid-day and afternoon traffic, when the number of passengers is small,—in some instances not averaging more than fourteen persons per train,—the steam motor coach will be used. Coaches of this type will be run just as often as is found necessary, and it is anticipated that there will be a large reduction in the general running costs. It is further surmised that such coaches as these will serve excellently for running on small feeder lines and for light railways.

THE general design is well shown in the illustration. The coach body is carried on a channel iron frame, which is 56 feet long over all, is borne on two four-wheel bogies, and is divided,—as regards its passenger accommodation,—into two compartments, first and third, these being separated by a sliding door. The first-class compartment, where the seats are placed longitudinally, is intended to seat ten persons. The third-class compartment, where the seats are arranged in pairs transversely on either side of a central gangway, holds thirty-two persons,—a total of forty-two in the two compartments. Access may be had to the coach at both ends from wide platforms which have openings on either side, these being closed, when running, by collapsible gates. There is a luggage van capable of holding one ton of luggage, and immediately in front of this are the engine and boiler. The latter is a vertical type. The two engine cylinders are inclined. 7 inches in diameter by 10 inches stroke, and the connecting-rods drive direct on to pins on the front wheels. The coach can be driven from either end, there being connecting-rods and levers to work the steam valve and brake handles, and it is calculated that it will be possible to attain a speed of 30 miles an hour in 30 seconds.

BY far the most interesting development in the recent labour troubles of American building contractors has been the clapping into jail of a walking delegate of one of the unions on a charge of extortion preferred against him by the president of a large works in New York which has been much harassed of late by union interference with its business. The arrest was the culmination of a long series of complaints which had been lodged against this particular individual with the district attorney during the past few months, all the charges being the same in effect,—that he had demanded and received money for declaring off strikes which he had previously

ordered. In the special case above referred to, he is accused of having first threatened a strike unless $1000 were given to him, of having ordered it when the money was refused, and of calling it off later upon receipt of a cheque for $2000. The arrest caused a sensation in labour circles, and is likely to be followed by the arrest of several other walking delegates on similar charges. The outcome of the proceedings promises to furnish direct proof of the long-suspected fact that the business of many a walking delegate is the trafficking in strikes for his own benefit and not for that of the blindly trusting men whom he is supposed to honestly represent. What may be shown to be true in this instance of the walking delegate is probably quite as true of many of those higher up in labour's circles. With rare exceptions, they are not the kind of men likely to devote themselves, even in a moderately unselfish way, to the uplifting of the labouring man.

SEVERAL very interesting samples of boiler scale were exhibited recently by Mr. C. E. Stromeyer in the course of a lecture before the Manchester Literary and Philosophical Society. The samples were of rare occurrence and resembled miniature volcanoes, their growth having been probably very similar to the growth of real volcanoes, except that instead of the added matter around the vents having been thrown up as dust and lava, it was extracted from the boiler water in which it was held in solution. Probably the raising of the land around mineral springs is the exact counterpart of the growth of these little boiler scale volcanoes, a group of three of which is shown in the annexed illustration. In the case of hot springs, as Mr. Stromeyer explained the action, surface water enters into a porous stratum, and, under favourable conditions, descends to a depth where it acquires a considerable temperature. Should there be openings there to the surface, this warm water will rise and overflow, carrying with it soluble and even insoluble matter, which, under favourable circumstances, deposits itself around the vent, whose top level may easily be raised to the level of the intake without in the least reducing the flow. Should the action of the hot spring continue for a considerable length of time, then its vent might rise to a considerable height above the intake, but only if the downtake channels descend to considerable depths. For obvious reasons this condition is most generally to be found near ocean shores, and it is here also that high volcanoes are most frequent. On first thoughts it might seem impossible for volcanoes like Chimborazo to have been built up in this manner, for the difference of pressure represented by a height of 27,000 feet above sea-level is greater than the difference of pressure due to down-flowing cold water and up-rushing superheated water and steam. Suppose, however, that this volcano had not grown; suppose that it had once been a mountain, and that imprisoned superheated water and steam had blown off its cap, then it is necessary to explain why this water, which must have been led downwards through some natural channel, should not flow back into the ocean instead of overcoming an earth pressure represented by at least



A CURIOUS BOILER SCALE FORMATION

twice the height of the mountain. It is possible to conceive this action with low mountains, and it is notorious that the most violent eruptions have occurred with them; but it is impossible that high volcanoes should have been formed in this manner. One notable feature of high volcanoes is that they are always active and their vents are always open; under such conditions, particularly as the core of such mountains must be very hot, these vents act almost like warm chimneys, and produce an upward draught which assists the already highly heated steam to escape. Should such a vent get closed, then most probably the superheated steam would be capable of exerting sufficient pressure to burst out at the base of the mountain. It is also possible that the gradual adjustment of the internal temperature may cause the mountain crust to crack through its old vent, through which the old activity would recommence. Amongst the specimens of boiler scale shown by Mr. Stromeyer the one here photographically reproduced is strikingly illustrative.

Almost all the work done by the manufacturing engineer is empirical; scientific knowledge has nothing to do with it, and the advocates of the higher training for engineers have always found this to be one of the great difficulties in their way. Quite recently *The Engineer*, of London, printed an interesting editorial on the subject which wound up with the conclusions that, generally speaking, "Molesworth" has played a more important part in engineering than all the text-books published in the last half century; and that perhaps, in the end, the best thing the colleges can do is to recognise empiricism, accept it as a tool, and utilise it. Some hours each week might be spent worse than in teaching the student to use cut-and-dry formulæ, without the slightest reference to what the formulæ mean, or the way in which they were obtained. As justification for this view, *The Engineer* assumed, among others, a case where a highly-trained man comes into a marine engine building works. A large triple-expansion engine of a somewhat novel type is being designed. So are the Scotch boilers. The new man's first job is to design the crankshaft. He works out the moments, settles the torsion limits, calculates all the stresses, and when he has finished finds out that he has wasted his time. Certain empirical rules were laid down long since for the proportions of crankshafts by Lloyds and the Board of Trade. These must be complied with. The probability is that his design does not in any way conform to these rules. So much the worse for the design. Turning to the boilers, he finds again that his path is carefully staked out for him. All the thicknesses, tensile strengths, materials, riveting,—in a word, every detail,—is carefully set forth, and must be followed. All that is left to him is the determination of the general dimensions, such as the length and diameter of the shell, and the number and diameter of the tubes. But this is not all. Let it be supposed that he is designing a land engine for a private firm, with which neither Lloyds nor the Board of Trade has anything to do, and that he has to fix, say, the diameter of the high-pressure piston-rod. He sees at a glance that he may neglect the tensile strength of the rod, because if it is strong enough as a column in compression, it must be very much too strong in tension. Now, there is no information available to him about piston-rods in compression that is not the result of experiments made by Hodgkinson, Baker, Unwin, and others. It is purely empirical, and has all been worked into cut-and-dry formulæ for him. He determines the diameter of his rod, and his next step is to settle how much bigger it ought to be. The factor of safety question comes in, and this utterly baffles mathematics and physics. One firm will make a piston-rod 4 inches in diameter; another will, for precisely the same stresses, make it 6 inches in diameter. Both rods are strong enough by large margins. It will usually be found, however, that the thinner rod will at some time in its life bend, and the thick rod will not. No

amount of high scientific training can enable the new works manager to settle, after all, what the best diameter is; and if he be wise he will reproduce dimensions that have been found to answer, no one knows precisely why. The chance that he can materially improve on these is very small. In point of fact, in every works certain general dimensions have been settled on the principle of the survival of the fittest. They represent the practice of the drawing office, and it is almost impossible for any engineer, however clever or original, to depart from these with advantage.

Again, it will be found that certain results have been obtained in practice which are not consonant with the teaching of text-books, or the instructions given in the college. It is not that the text-books or teaching are wrong. It is simply that the conditions are not identical. If, for example, we have such a question as the ventilation of a mine to consider, the apparently arbitrary empirical rules used for proportioning the dimensions and speed of the fan, drawn up by men of large experience in this class of work, scarcely ever agree with the rules which the mathematician lays down, and it is quite safe to say that a man whose knowledge of mine ventilation was acquired wholly from lectures or reading would make woeful mistakes if he were called upon to design plant for ventilating a colliery of any size.

Quite in line with this are a number of points emphasised in an address made by Mr. P. M. Lincoln a week or two ago before the Canadian Electrical Association, and having for its subject the training of the high-tension electrical engineer. The technical graduate, as Mr. Lincoln remarked, may have knowledge in plenty, but his wisdom is to come. Put to the fresh college graduate, for example, the problem of the amount of distance to be left between the conductors of a high-tension transmission line. His answer most likely will involve the jumping distance of the voltage to be used, the length of span, the sag, and perhaps a liberal factor of safety. It is experience only that will show that his premises are wrong, and that the equation to determine the spacing of high-tension wires depends very little on the voltages to be carried and almost entirely on such things as the average length and ohmic resistance of cats, the spread of wings of owls, and cranes, and eagles, and the average length of scrap baling wire, together with the strength of the average small boy's throwing arm.

Experiments have shown that the phenomenon of the speaking arc lamp, referred to in these columns recently, is not confined to the electric arc lamp, but that the Bunsen and other similar lamps are capable of reproducing speech under conditions practically similar to those employed in the case of the electric arc, one terminal of the secondary of the usual induction coil being introduced into the flame, the other attached to the metallic burner of the lamp. The primary of the induction coil is in series with a battery and a microphone transmitter, which is placed some distance from the flame. When the transmitter is spoken into the voice is clearly reproduced by the flame.

Concerning the matter of accidents due to combustion within air compressor cylinders, recently referred to in these pages, Mr. W. L. Saunders has contributed a brief memorandum to the transactions of the American Institute of Mining Engineers touching upon precautions to be taken against such mishaps. In the first place, he advises the use of a compound compressor. By compressing the air in stages, that is, by the use of compound cylinders, the maximum temperature during compression is very much reduced and the liability to "flaming" is less. Having

an air compressor with compound cylinders, the next thing to do is to provide a high grade of oil to be used in the cylinders. This should be an oil with a high flashing-point and of a non-coking nature. In other words, when the oil is placed on a shovel and held over a fire there should be little or no carbon deposit left after it has been volatilised. The third point to be observed is to caution the engineer not to use much oil in the air cylinders. A drop every five minutes is sufficient in a cylinder of ordinary size, and every engineer should feed soapsuds into the cylinders at least one day in the week, in order to wash away any deposit which may have accumulated through the use of oil which has been acted upon by highly heated air. The soapsuds may be fed through the regular oil cup. Care should be taken not to let the machine lie idle with soapsuds remaining in it; that is, shortly before quitting-time the feeding of soapsuds should be stopped and oil feeding substituted.

ANOTHER point is that every engineer should look into the discharge valves, air receiver and other places where deposits are liable to accumulate, and keep them clean. A discharge valve which sticks, either through defective construction or through the accumulation of carbon around it, is liable to admit hot compressed air from the receiver back into the cylinder and thus increase the temperature of the air to be compressed so greatly as to reach the flashing point of the oil. In connection with this, it is well, also, to bear in mind that the intake air should come from the outside, and not from the inside, of the engine room. This is important, because a cold intake gives a higher volumetric efficiency to the compressor, and also because it results in a lower maximum temperature during compression, which not only means safety against "flaming," but economy of power. The hotter the air is during compression, the greater is the resistance to compression. Another reason for an outside intake is that bad air in the engine room, or smoke or fumes from a fire, will not be sucked into the compressor and discharge into the mine. Mr. Saunders also emphasised the value of inter-coolers and after-coolers in a compressed-air plant. These coolers are surface condensers, the inter-cooler being placed between the high and low-pressure air cylinders, and serving to reduce the temperature between the two stages of compression. The after-cooler reduces the temperature after the last stage, and condenses and collects all such foreign matter as oil, moisture, dust, etc., sending pure, dry air down into the mine.

A SOMEWHAT novel committee has recently been appointed by the American Institute of Electrical Engineers, the duty of which will be the gathering of data of use in the electrical engineering profession, especially with regard to new and special subjects. It is thought that many engineers may have curves, short methods, empirical formulæ and other data of great value, which they might be willing to give to the profession through the Institute. Such data are, however, usually regarded as trade secrets, so to speak, by the possessor, and, as a rule, are the result of much arduous work on his part, and consequently are naturally closely guarded from outsiders; but as engineers are, in the main, inherently generous, it may be that some important information will be procurable by the committee. The attempt to secure data of the character mentioned is certainly worth the making, and it is to be hoped that the committee will meet with success.

PHOTO BY PHILLIPS, PHILADELPHIA

A RECENT PORTRAIT OF DR. COLEMAN SELLERS

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WATER FOR THE GOLD FIELDS OF WESTERN AUSTRALIA

By D. M. Bates

THERE was recently completed, by the opening of the gold fields water scheme in Western Australia, one of the greatest engineering feats in the history of that country, —one whose importance and far-reaching results can be fully comprehended only by those who possess a knowledge of the aridity of the gold-bearing districts of Western Australia. In almost all the other States water can be obtained inland by boring. In Queensland, and Central Queensland especially, artesian wells have been sunk far inland with astonishing results. But in Western Australia, the peculiar geological formation of which differs from that of every known country in the world, there is no artesian water in the interior. Water is found in the pastoral and agricultural districts at varying depths,—sometimes 11 feet, sometimes 2000; the water may be good, bad, or indifferent. It is more often the two latter. But such as it is, it has to satisfy the wants of the communities that arise in the various parts of the State.

It is a curious fact in Western Australia that the most payable gold is found in the most arid and remote places, and in the strangest conglomerates that have ever come under the notice of geological and mining experts. Stone and ore differing altogether from gold-bearing stone in any other part of the world has been found in West Australia. The inland portions of the State are one vast auriferous field awaiting only the trend of population to open up their gigantic resources.

However, to dilate upon this matter is to digress from the subject in hand. The history of the gold fields of Coolgardie and Kalgoorlie must, by this time, be familiar to the English peoples, so I will confine myself to writing an account of the great water scheme which has revolutionised the workings of the fields and opened the way for a larger increase of prosperity than that which they had hitherto possessed, great as it was acknowledged to be.

In the spring of 1892 the discovery

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A VIEW OF THE DAM AT MUNDARING. THE TOP OF THE DAM IS 100 FEET ABOVE THE BED OF THE HELENA RIVER

of gold in Coolgardie not only led to the developments which have won for these districts a world-wide reputation, but it also brought the people of West Australia face to face with a very serious problem, for the regions where the original rich finds had been made were arid, unpopulated, and far distant, with the great essential of life-water almost unprocurable.

When the wonderful developments of Coolgardie resulted, as was expected, in an abnormal flow of population to that district, the inability to procure water in sufficient quantity led the government to take prompt measures to

THE WATER IMPOUNDED EXTENDS OVER SIX MILES BACK OF THE DAM

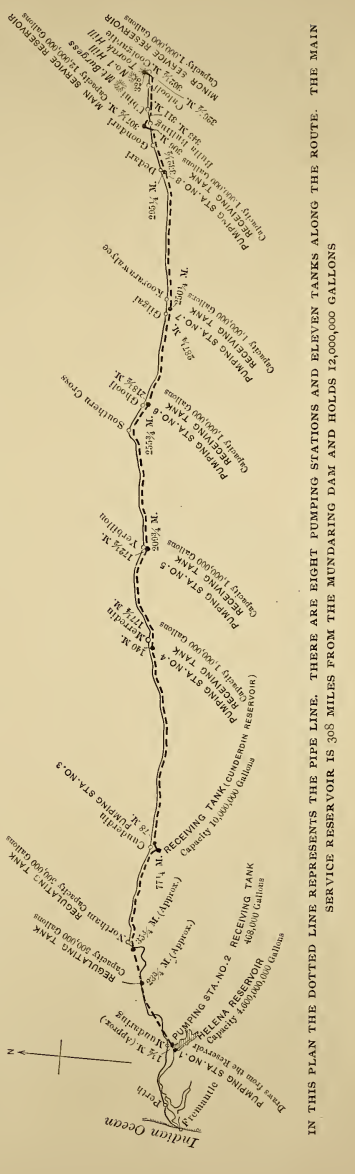
find adequate supplies for the incoming thousands. Fortunately for the pioneers, the season in 1892 was remarkable for its heavy rainfall, more than has since been experienced on the fields. Hence the outlying districts were abundant in rich grasses, while water lay on the surface of the ground and was easily obtainable from rock-holes all along the route.

In the summer of 1893 and 1894 the rainfall upon the eastern gold fields had been so very scanty, and there had been such a rush of people to these fields in consequence of their marvellous progress and their great wealth, that a dire need of water was beginning to be felt. The necessity had been accentuated by the extension of the railway system to the fields, and it was only by the most energetic measures on the part of the government, coupled with the expenditure of enormous sums of money upon what were more or less temporary alleviating measures, that a great calamity was avoided.

In those days water on the gold fields cost two and sixpence per gallon, and hotel keepers were wont to more jealously guard the water bag than the whiskey bottle. As to water for bathing purposes, it was altogether too precious to waste in washing.

This necessity for procuring a sufficient, as well as a permanent, water supply had forced itself so strongly upon the attention of the government that in the years 1894 and 1895 they were considering how that supply could best be brought about. Various proposals were brought forward from time to time, but they were mostly for condensing on a large scale on the salt lakes situated in different parts of the fields. These proposals were abandoned for various reasons, amongst them being the scarcity of fuel for condensing purposes, and the uncertainty of a permanent supply of even salt water.

In the meantime twenty-four tanks were erected on the gold fields at a cost of £255,000, but these measures were acknowledged by all to be only temporary. Bore holes had been sunk to a depth of 3000 feet at Coolgardie


Indian Ocean
Perth
Fremantle
PUMPING STA. NO. 1
PUMPING STA. NO. 2
PUMPING STA. NO. 3
PUMPING STA. NO. 4
PUMPING STA. NO. 5
PUMPING STA. NO. 6
PUMPING STA. NO. 7
RECEIVING TANK (CONDENSER RESERVOIR)
RECEIVING TANK
RESERVE TANK
RESERVOIR
Southern Cross
Coolgardie
Kalgoorlie
Boulder
Kanowna
Menzies
Yerilla
Widgiemooltha
Norseman
Dundas
Balla Balla
Parker's Range
Mundaring
Helena
Darlington
Gooseberry Hill
Guildford
Midland Junction
Spencer's Brook
Belmont
Cloverdale
Victoria Park
Burswood
Claremont
Cottesloe
Subiaco
Perth
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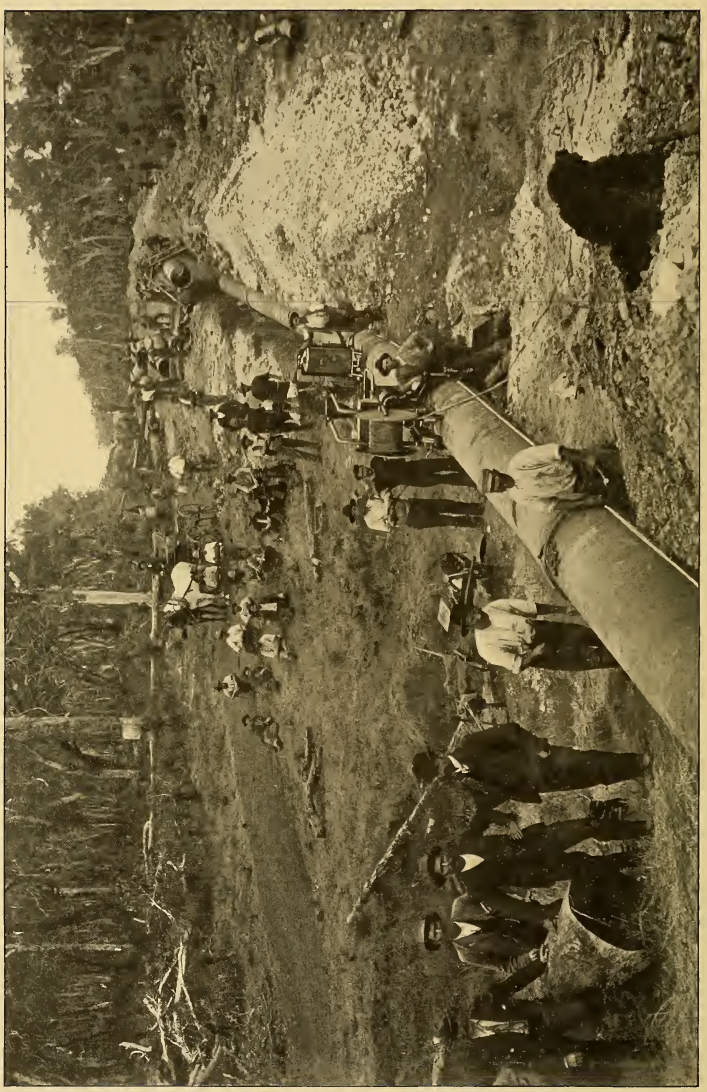


LAYING THE PIPE. THE LONGITUDINAL SEAM OF THE LOCKING-BAR PIPE IS VERY CLEARLY SEEN HERE. SEE PAGE 285

without finding water. In 1895 Mr. C. Y. O'Connor, the engineer-in-chief of Western Australia, was asked to submit proposals for the supply of a large quantity of fresh water to Coolgardie, and after due consideration it was decided to prepare a scheme for pumping water from reservoirs to be placed at sites selected in the Darling ranges, and the immediate collection of the necessary data was taken in hand. Estimates were asked for on all matters connected with plant; examinations of the various catchment areas were made; information was collected regarding the engineering details necessary for a complete supply system, together with the heights of prominent hills contiguous to the railway line.

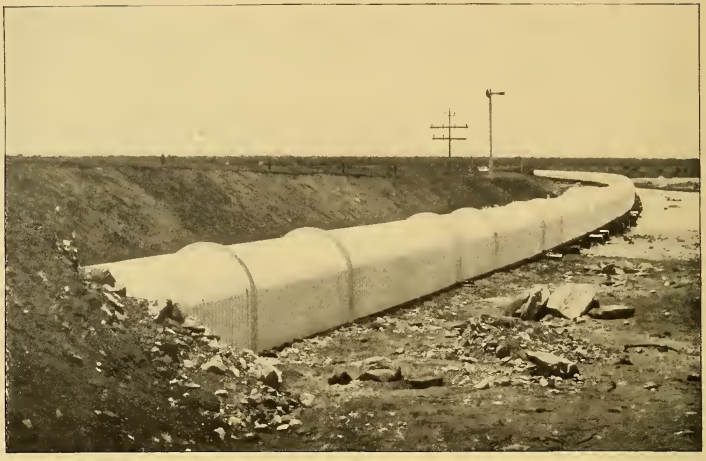
After months of careful study Mr. O'Connor was enabled, in July, 1896, to formally present his project, now known as the Coolgardie Water Scheme, to Parliament. This was carried through its various stages, and £2,500,000 were voted for the undertaking. Thirty-one proposals and estimates were prepared, and out of these one was selected which was to supply 5,000,000 gallons per day through a steel pipe 30 inches in diameter.

The engineer-in-chief went to England in 1897 in order to discuss some of the phases of the scheme with specialists. During the nine months that he was away he was in constant communication with the board of experts who were considering the details of the Coolgardie enterprise. He also visited many of the large manufacturing centres in order to ascertain first-hand the prices at which the enormous quantities of material required for the scheme could be purchased. The final report of the experts was submitted early in 1898, and tenders were at once called for the supply of pipes. The contract was secured by two Australian firms,—Mr. Meysham Ferguson, of Melbourne, and Messrs. G. & C. Hoskins, of Sydney. The transaction was formally signed on October 18, 1898, the amount involved being £1,025,124.

In the meantime the financial part of the scheme proved to be more difficult to handle than had been anticipated. Consequently, when Parliament opened in October, 1897, the Governor's speech contained a clause which stated that "in consequence of other large works already in progress from loan funds, some little delay must occur before the great Coolgardie water scheme could be undertaken; but the necessity for a certain, cheap, and good supply of water to the fields was imperative."

Owing to this delay and also to the tightness of the foreign money market, the opposition to the scheme was industriously renewed, and advocates of its being carried out by private enterprise became very numerous. M. Bargigli, a French engineer, representing a Paris syndicate, came to Perth in 1897, and offered to carry out the whole of the scheme, according to Mr. O'Connor's design, for £2,230,000,—twenty thousand pounds less than Mr. O'Connor's estimate. The government, however, declined the offer twice.

To Mr. A. E. Morgans, the member for Coolgardie, must be ceded the credit for having the work pushed on vigourously until it had reached its finality in the arrival of the water at Kalgoorlie. The progress of this scheme through Parliament has been so unique and the attacks and renewed attacks which have been made upon it are such a feature of its existence that to omit all reference to them would be to fail to give an intelligent account of its history. The government carried out the work of trench digging, laying, and jointing of pipes departmentally. The jointing of the pipes was being mechanically performed by an ingenious and special invention. Complaints were freely made that the device was a failure, and that jointing by hand could have been much more economically and expeditiously carried out, and, as a result of these and other complaints, Parliament appointed a select committee to deal with the whole question. Later on this was transformed into a royal commission. During the early stages of the commission's operations the people of Western Australia were horrified to learn of the death, by suicide, of Mr. C. Y. O'Connor, the



WHERE THE WATER PIPES ARE ABOVE GROUND, THEY ARE LAID ON TRESTLES AND ARE THEN COVERED WITH CORRUGATED IRON ON WOODEN FRAMES, WITH THE INTERVENING SPACE PACKED WITH SAWDUST

A TRAIN LOAD OF THE LOCKING-BAR PIPES

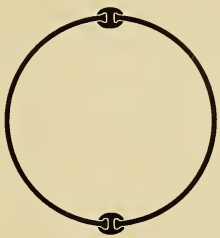
engineer-in-chief. Mr. O'Connor had been hard at work preparing for the commission, and the heavy burden of his labours no doubt temporarily unhinged his mind. A few days later an official test under actual conditions of work was made with a seven-mile section of the pipes which was highly satisfactory, and which was shortly supplemented by the water reaching Northam.

The final report of the commission was highly favourable to the practice of carrying out large public works departmentally. On the conclusion of the commission's labours a marked increase in the progress of the undertaking was perceptible, with the result that the scheme reached its final stage in January of this year, when the formal opening took place.

The historic sequence of the enterprise requires some reference to the locking-bar pipe which is used. The links between the Mundaring weir and the gold fields are the pipes, and special pipes at that, and but for the class of pipe used in this gigantic work this year would not have seen the water flowing into Kalgoorlie. To Meysham Ferguson, of Melbourne, rising from the smithy forge and working his way against difficulty piled on difficulty, belongs the honour of being the inventor of a pipe which has saved the government not only thousands of pounds, but has caused the completion of the work in record time. While the late Mr. C. Y. O'Connor, the designer of the scheme, was busily engaged inspecting the world's greatest pipe and pump-making establishments, Mr. Ferguson's mind was focussed on devising the locking-bar pipe. His mind was bent on simplifying the spiral method and improving on the cast iron process. One evening about midnight as he was thinking over the complex subject, the unravelling of which meant a fortune to somebody, an idea suddenly struck him which, with a lead model, he soon converted into a reality. Early next morning, at Footscray, Melbourne, a pipe was made, and from that day success has followed the inventor.

In 1898 tenders were called for the supply of pipes, and there was great and keen emulation for the contract. Meanwhile, Mr. O'Connor visited Mr. Ferguson's works, and after investigating the merits of the locking-bar pipe, had no hesitation, after the tenders had been duly considered, in recommending it. Mr. O'Connor reported that it was the best class of pipe he had seen in all his travels.

Just what the pipe is will be best apparent from the diagram on this page. The principle of the "locking-bar" pipe, which is merely a method of expressing what one knows more familiarly as a pipe having one or more longitudinal seams joined together by a channel bar of soft steel, the flanges of which are pressed on to the edges of the plates until a tight joint is effected, is not exactly new; but the difficulty with pipes with this class of joint has been the designing of machinery which would make it with sufficient rapidity and certainty. This Mr. Ferguson, however, has done.



A CROSS SECTION OF A LOCKING-BAR PIPE. THE NATURE OF THE LONGITUDINAL JOINT IS HERE CLEARLY SHOWN

The pipes are made of two plates of equal widths, and the locking bars and joints are exactly opposite each other in the formed-up pipe, so that both joints can be closed by pressure exerted in a straight line.

The first contract was for a twelve-mile stretch. A great deal of attention was directed to the detection of leakage. The pipes were put under full pressure for twenty-four hours, but successfully resisted the strain, the valves being responsible for a leakage of only 100 gal-

FILLING THE RESERVOIR AT COOLGARDIE

lons. The next contract was for a thirty-one-mile run, the whole of the joints being hand-calked, which Mr. Ferguson holds to be the best method of closing the joints. The third contract was for eight miles. On the test being applied, not a leak in any joint was detected, and so satisfied was Mr. O'Connor with the result of his investigations that, so far as he was concerned, Ferguson's locking-bar pipe was to be the channel of communication between Helena Vale and the gold fields.

The reasons why the locking-bar pipe was classed ahead of any known riveted or cast iron pipe were threefold:—1. Less tendency to leak. 2. Stronger for equal weights. 3. Causing much less friction than rivetted pipe. Another advantage might well be added,—economy in handling and hauling. On September 8, 1899, the first locking-bar pipe was made by Mr. Ferguson for the gold fields water scheme, and the last one on September 30, 1901. In view of the colossal nature of the work, it had been asserted that the pipe contract was too big for any two firms in the world, and the securing of the contract was considered likely to be a battle royal between British, Continental, and American manufacturers, with no thought of Australia in the matter, though Australia, as it turned out, beat the world in this competition. Each pipe was 28 feet long and 30 inches in diameter.

Now as to the site and distance:—The Helena River was the one chosen to provide the supply for the fields, the flow being impounded at a point five miles from Mundaring station and about twenty-five miles from Perth. Seventeen localities in all were inspected, and the position of the present dam site, where the hills converge to a narrow space and the country for miles round is flattened out, was apparently the best. An oversight occurred in not calling upon the government geologist to examine the ground before work was started, and as a result a serious fault was discovered too late, as also a lesser trouble of a huge detached boulder, both of which caused much extra work and expense.

The top of the dam is 755 feet in

length, traversed by a neat iron lattice bridge over the crest, which is 100 feet above the bed of the river. The dam tapers in thickness from 75 feet at the river bottom to 10 feet at the top. As a maximum the sheet of water will be thrown back six or seven miles. The quantity of water is set down as 4,600,000,000 gallons. Alongside the dam is a tower which gives access to a number of valves allowing the water to be drawn off at various levels, while at the foot of the wall a scour valve permits the removal of any silt which may accumulate.

Exterior to the dam and a little lower down the gully is the first pumping station, and the second one is only a mile and a half from it, but 400 feet above it. Here is situated a receiving tank with a capacity close to half a million gallons. In all there are eight pumping stations and eleven tanks or reservoirs, with capacities from half a million to 12,000,000 gallons. The main service reservoir is 308 miles from the dam, and its capacity is 12,000,000 gallons. The minor service reservoir at Coolgardie holds a million, and the Mount Charlotte reservoir at Kalgoorlie, two million gallons. Receiving tanks of one million-gallon capacity were built at five of the pumping stations. A reserve tank for railway purposes was also built at a point along the route, and there are two regulating tanks holding 500,000 gallons.

The level of the water at the lowest off-take at the dam reservoir is 340 feet above the sea, but so rough is the country and rising that within a little over three miles an altitude of over a thousand feet is reached. Twenty-four miles from the dam the regulating tank is

AN ELECTRIC CALKING MACHINE AT WORK ON A PIPE-LINE JOINT

1065 feet above sea level, and then it gradually drops 100 feet in the 12-mile interval. The next regulating tank is only 476 feet above the sea. After this the water flows by gravitation for 42 miles until it empties into the reservoir, which is 780 feet above the sea.

The next pumping station, 63 miles away, is 980 feet above sea level, and 32½ miles further on is No. 5 pumping station, 1293 feet above sea level. The level varies only 32 feet within the next section of 46 miles, which terminates at No. 6 station. In another short length of 32 miles a rise of 86 feet is experienced over the last. No. 7 section is 45 miles, and finds a rise of only 36 feet to No. 8 pumping station. Twelve miles further is the site of the main service reservoir, at 1610 feet above the sea and 1270 feet above the lowest take-off at the Mundaring reservoir.

From there the Coolgardie reservoir is 10½ miles and the level 1515 feet above the sea, so that the water will drop 95 feet to Coolgardie, and from there to Mount Charlotte at Kalgoorlie, 27 miles away, there is a further drop of 160 feet, for the last reservoir is 1355 feet above the sea. Here, at a distance of 328 miles from the dam, the pipes at present terminate, but before long they will be extended "further east."

From the illustrations accompanying this article the peculiar method of laying the pipes over the salt lakes and above ground will be seen. The attraction of heat by salt lakes is so well known that it hardly needs remark. The pipes are first laid on trestles and then covered with corrugated iron on wooden frames, with the intervening space packed with sawdust.

The formal opening of this great scheme took place last January, the Right Hon. Sir John Forrest, the founder of the scheme, performing the opening ceremony. The occasion was an historic one. Federal ministers, representatives of all the States in the Commonwealth, were present to witness the completion of what is rightfully considered as one of the greatest engineering feats of the age. To many of the visitors the great wealth and progress of West Australia came as a revelation, and the fact that Kalgoorlie in the year that had just passed turned out approximately 1,000,000 ounces of gold, representing half the total output of the State for the same year, did not diminish the wonder of the visitors at the marvellous richness of the eastern gold fields.

The scene at Coolgardie, on the turning of the tap which threw a jet of water some 20 feet into the air, will live long in the memory of those who witnessed it, and at Kalgoorlie, when the huge pipe through which the water flows into Mount Charlotte reservoir discharged its contents in an abundant stream, and the words of Sir John Forrest, which he had uttered at the inception of the scheme and now at its completion,—"They made a way in the wilderness and rivers in the desert,"—were heard by the people assembled, such a cheer went up from the thousands of lusty throats that even Sir John felt that his life's work had reached its apex, and that not the least of the public works which he had carried through during his ten years' premiership of West Australia was the successful completion of the Great Gold Fields Water Scheme.

The town of Kalgoorlie has been seven and Coolgardie twelve years in existence. It speaks much for the enterprise of the gold fields people, as well as of the wealth of the mines, that such rapid progress should have been made, and, taking into consideration the distance from the coast, the projection of a railway, and the fact that all the materials for the building of these cities had to be brought from Perth, and that such a city as Kalgoorlie should have been so far advanced in the short space of seven years, it must be admitted that the gold fields people are deserving of the greatest praise for their enterprise.

This article must not close without a tribute to the present Minister for Works, Mr. C. H. Rason, who assumed office in January, 1902, and whose work in promoting the rapid completion of the great scheme has been untiring in its energy. He has acquitted himself of his high duties in a manner that no other man in the State could have surpassed.

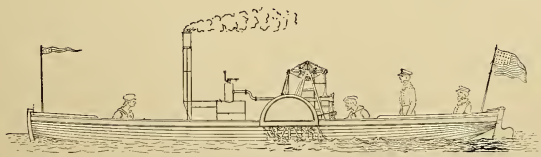
MODERN AMERICAN LAUNCH MOTORS

By W. P. Stephens

THE power launch, that important medium of modern sport, as well as business, is so essentially a development of the present generation that it is commonly classed with such recent inventions as the telephone and the motor car. As a matter of fact, it can show a far greater antiquity, and, small as it is, it can justly claim to be the parent of the great ocean liners. The early experiments in the application of the steam engine to marine propulsion and in the development of, first, the paddle wheel and then the screw propeller, were, of necessity, made in craft that to-day would be classed among the smallest of launches.

Coming to the time when commercial success was actually in view for the steamboat, we find some interesting records of experiments intended not to demonstrate the mere practicability of the application of steam power to vessels, but to raise the infant science of marine engineering to a much higher plane than it then occupied. The experimental machinery, built in 1804 by Colonel John Stevens, of Hoboken, New Jersey, and tried in that year on the Hudson River, embodied five principles which were at that date new and radical, but which are to-day the basis of the most advanced marine engineering. These were the quick-moving engine directly connected to the shaft; the multi-tubular boiler; high-pressure steam; the short, four-bladed propeller; and twin screws. The hull in which this interesting plant was installed was little more than a "Whitehall boat," the light boat used at that time by the watermen of New York Bay for ferriage and communication with vessels at anchor. It was about 18 feet long and 5 feet beam.

In all the early experiments the small boats at first used were, in turn, discarded for larger and larger ones, the one aim in view being the production of craft of such size and tonnage as to be seaworthy and capable of carrying passengers and freight in competition with the existing sailing packets, and it was not until 1837, by which time the river and coasting steamer was an assured success and the day of the ocean steamer was at hand, that a deliberate attempt was made to utilise steam for the propulsion of very small craft. The first attempt of which any record is to be found, in the United States at least, is



From "Haswell's Reminiscences." Copyright, 1896, by Harper & Brothers.

HASWELL'S STEAM LAUNCH "SWEETHEART," 1837

A NAPHTHA LAUNCH, BUILT AND EQUIPPED BY THE GAS ENGINE & POWER CO. AND CHARLES L. SEABURY & CO., CONSOLIDATED, MORRIS HEIGHTS, NEW YORK CITY

that of the now venerable Charles H. Haswell, the eminent engineer, of New York, who at that time was the first engineer-in-chief of the United States Navy. The craft used by him was one of the Navy cutters of the day, propelled by oars, Mr. Haswell constructing a small beam engine with paddle wheels by which he was able to run her on the East and Hudson rivers.

While the possibility of applying steam to the propulsion of boats had been demonstrated at a very early date, up to the time of the American Civil War the machine shops of the day were limited in their facilities, and little attention was paid to small work. Both engines and boilers were crude in design and construction, and excessively heavy. About 1870 material improvements were made, the attention of engineers being seriously directed to the problem of the torpedo-boat and of the pleasure and service launch. Among the pioneers in the production of really efficient steam launches for both war and pleasure was John B. Herreshoff, of Bristol, Rhode Island, and his younger brother, Nathaniel Greene Herreshoff, now the heads of the famous Herreshoff Manufacturing Company. The first Herreshoff torpedo-boats were notable in their day for the general excellence of their design and construction and the many novel ideas of their builders, and the Herreshoff steam yachts were not only the fastest of the time, but were practical and useful.

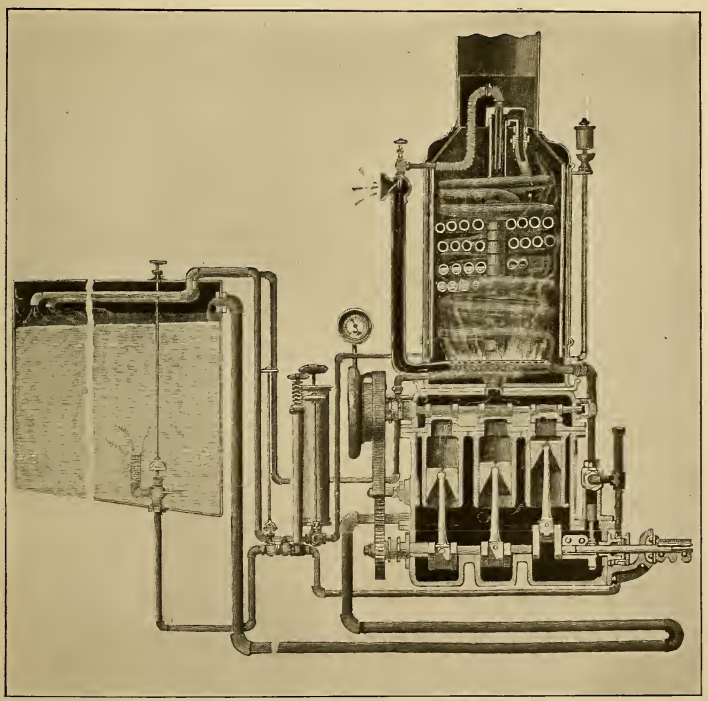
The disadvantages of steam increase in a rapid ratio as the size of the hull decreases; the weight of engine, boiler, furnace, tanks, and bunkers is excessive in comparison with the size of the hull, and this weight must, of necessity, be carried amidship, taking up space and in the best part of the boat. The heat of the furnace and boiler makes a small launch uncomfortable in any but the coldest weather, and is particularly trying in the smaller sizes of cabin launches; there are always smoke, coal dust, cinders, ashes, to say nothing of the smell of hot dirt and oil.

The first step in the reduction of these disadvantages to such a minimum that the steam launch could, with reason, be classed as a pleasure craft, came at the hands of the Herreshoffs and a few other

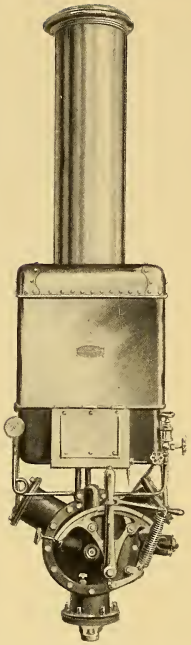
contemporary experimenters in the designing of a special launch engine of compact form and moderate weight, with a pipe boiler, giving a great saving in weight and gain in efficiency over the old vertical tubular boiler with its big reservoir of water and high centre of gravity. The improvement in this line was so marked that, with a properly designed hull of light construction, a party of fishermen or tourists could be carried in comparative comfort and at a speed of a dozen miles per hour. Between 1875 and 1880 the steam launch in this form attained popular recognition from yachtsmen, summer tourists, hunters, and fishermen, and, to a certain extent, from business interests.

One great disadvantage of the most improved launches was in the use of coal as fuel. A comparatively large space next to the boiler was required for the bunkers; there was dust from the coal whenever the bunkers were filled, and from the ashes and cinders at all times when under way; a long time was required for starting the fire and getting up steam, and the furnace was slow in cooling after a run; then, too, it required the full time and attention of one man on any but the smallest launches to feed and tend the fire and remove the ashes.

The next step in the line of improvement was obviously the substitution of



A SECTIONAL VIEW OF THE MOTOR AND NAPHTHA VAPOUR GENERATOR OF THE GAS ENGINE & POWER CO. THE NAPHTHA TANK, GENERALLY LOCATED IN THE BOW OF THE BOAT, IS SHOWN AT THE LEFT. NAPHTHA VAPOUR IS USED IN THE ENGINE AS STEAM IS USED IN A STEAM ENGINE. THE VAPOUR IS NOT EXPLODED TO PRODUCE MOTION

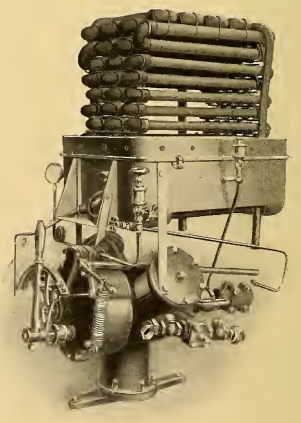


A 7 H. P. ALCO-VAPOUR ENGINE AND RETORT, MADE BY THE MARINE ENGINE & MACHINE CO., NEWARK, N. J. THE VAPOUR OPERATING IN THE ENGINE IS GENERATED FROM A MIXTURE OF ALCOHOL AND WATER

liquid fuel for coal, and about 1880 many experiments were made along this line. Kerosene was the favourite fuel, owing to its low cost and the ease with which it could be obtained. But a serious difficulty was encountered in the use of both kerosene and the heavier oils in the deposits of carbon on the burners, clogging them and extinguishing the fires. A number of kerosene and oil burners were patented and placed on the market, some of them as integral parts of very light and compact marine plants; but none proved completely successful.

It is probable that satisfactory results along modern lines would have been achieved at this time but for an unexpected development in an entirely new direction, resulting in the production of what is popularly known as the "naphtha engine." This is in reality a steam plant; but naphtha is used, from one single reservoir, as both fuel and the medium for the generation of the expansive vapour. The boiler is a simple coil of tubing, to which the naphtha passes, a small portion being diverted by a special pipe to a retort at the base of the coil. The flame from this retort or torch vapourises the naphtha within the coil, and this vapour passes downward to the engine which forms the base. This is a three-cylinder, fore-and-aft tandem machine, with trunk pistons, single-acting, and of very simple and durable construction. The naphtha vapour serves incidentally to lubricate the cylinders without the use of special oils. Passing from the engine, the vapour is condensed by a pipe outside the boat which returns it to the tank, the only waste being that consumed by the torch.

This ingenious plant, the invention of a clever German mechanic, Frank W. Ofeldt, of New York, is admirably adapted to marine use. The engine, boiler, and retort are so compact in form and light in weight that they can easily



VIEW OF AN ALCO-VAPOUR RETORT WITH JACKET REMOVED

be placed in the extreme after end of the boat; the naphtha tank is preferably placed in the extreme fore end, where its weight balances the machinery, and where it is at the greatest possible distance from fire and heat. A sufficient length of condensing pipe is thus also easily obtained without bends. On its perfection in 1885 the naphtha engine was taken up by a company specially formed for the purpose,—the Gas Engine & Power Company of New York,—and with adequate capital and good business management a large business has been built up.

It was just at the time of the great yachting revival following the races for the America Cup between *Genesta* and *Puritan* in 1885, *Galatea* and *Mayflower* in 1886, and *Thistle* and *Volunteer* in 1887 that the "naphtha launch" in constantly increasing numbers became noticeable throughout the yachting fleet, at first in the form of yacht tenders, producing a revolution of the utmost importance. The smallest size of motor, the one horse-power, weighing but 150 pounds complete, could be easily carried in a yacht's dinghy of 10 feet length, and at the same time was powerful enough for a 16-foot boat. In either case only one man was required to run both engine and boat, while the machinery was so simple that special skill or mechanical training was unnecessary. It has proved in practice that the average seaman is fully competent, with a little instruction, to care for and run the launch. Where with a rowing boat four men would be taken from the yacht, perhaps for a couple of hours, to carry the owner ashore or on a visit to another yacht, only one man was necessary for the launch, and the service was performed in much less time. This of itself often permitted a reduction of regular crew, as in any yacht a certain number must be left on board in addition to those required for the crew. The naphtha tender, with no muscles to tire, also proved a good friend in the case of a calm or foul tide, being capable of towing at a moderate speed a yacht of considerable tonnage.

At this particular time the fleet was in a process of transition, the old shoal models were being discarded, and modern craft of much greater draught were taking their places. Where a schooner of 80 feet waterline of the old type would lift her centreboard and anchor close to the club float, a 40-foot cutter would, of necessity, have to anchor in a couple of fathoms of water, well off shore. Here, again, the power launch came in, making the run from the yacht to the shore, —perhaps formidable under oars in darkness and rough water,—but a simple performance. Though possessing certain disadvantages and destined, in time, to be rivalled by several other forms of power, the naphtha launch is entitled to much credit as a pioneer, and as a most important factor in the general development of yachting at a vital period.

With the successful growth of the Gas Engine & Power Company came larger engines and greatly improved hulls of various types; one of the most popular was the open launch of 20 to 30 feet, for general pleasure use; another was the cabin launch of 35 up to 75 feet. In all of these launches, regardless of size, only one man was required to care for and run the engine, and the work itself was so light and simple that many yachtsmen were well content to act as their own engineers rather than to be troubled with a paid hand in a small craft. These useful craft have found their way to the smallest and most remote waters of the United States and Canada, and, in fact, all over the globe; they are in use very extensively for hard service in fishing and commercial work.

To Mr. Ofeldt is due another motor, since perfected and developed by the Marine Engine & Machine Company, of Newark, New Jersey, under the name of "Alco-Vapour" motor. This is, in principle, a steam engine, with three cylinders placed at 120 degrees, and with trunk pistons; but in this case the fuel is kerosene, while the vapour is generated from a mixture of alcohol and water in a closed circuit, the exhaust being condensed and returned to a bow tank. As there is practically little waste, a large percentage of alcohol may be

A NAPHTHA LAUNCH BUILT FOR HIS MAJESTY THE GERMAN EMPEROR BY MESSRS. ESCHER, WYSS & CO., ZÜRICH, SWITZERLAND

used at small expense; but in case of necessity the engine may be run on water alone. The engine, with its retort and boiler superimposed, the latter composed of a series of spirals formed from small copper tubing, is compact and of light weight, and may be arranged in the stern. It is efficient and very simple in operation, "steam" being raised in a very short time, owing to the low boiling point of alcohol. It is built in various sizes, from 1 to 18 horsepower.

The basic principle of the steam engine, the motive force being a vapour generated by fire in an independent reservoir, is of almost unknown antiquity; but of late years the steam engine has found a rival of formidable proportions and comparative youth in the "explosion" or "internal combustion" motor. In this type of engine both fire and boiler are dispensed with, and the gas or vapour is generated prior to each stroke, directly within the cylinder. The first experiments, dating back about two centuries, were closely in line with artillery practice, a charge of gunpowder being injected into a cylinder and exploded, giving an impulse to the piston.

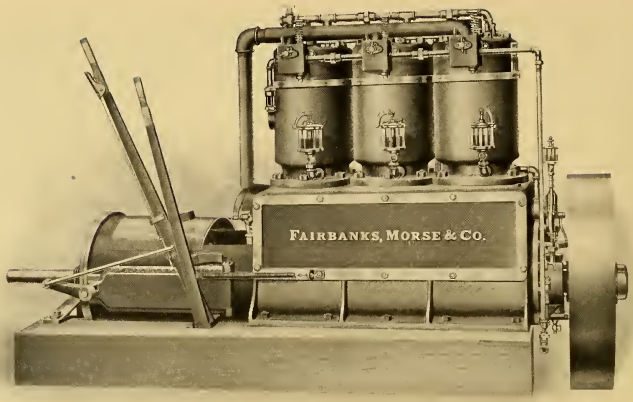
It is only within the last thirty years, after an infinite variety of experiments, that practical results have been achieved; but so great has been the progress within a few years past that it is already a serious question where the line is to be drawn between the steam engine and the "gas engine." In the smaller sizes and for certain uses,—in particular for the launch and the motor car,—the new power is already superior to steam, and steady progress is being made in increasing the size for stationary work.

The average layman, though utterly unversed in mechanical matters, has a fairly definite idea of the operation of the steam engine, with the steam generated in a metal boiler, just as in a kettle in his home kitchen, and the admission of this steam alternately to one end or the other of a closed cylinder where it pushes up and down a movable piston with a rod attached. The steam engine is such a familiar, every-day affair in the form of the locomotive and the ferry-boat engine that one can hardly be ignorant of its general construction and nomenclature. The "gas engine," on the other hand, is newer and less commonly seen, and is endowed with an absurd and complicated system of nomenclature which bewilders the beginner. It is spoken of indiscriminately as "internal combustion motor," "explosion motor," "hydro carbon motor," "gas motor," "gasolene motor," "naphtha motor," "spirit motor," and other similar terms. Of these the first four, referring to the principle of operation, are correct; the others, referring to the specific fuel used in individual cases, are incorrect, in that they are indefinite and misleading.

It is, in effect, a motor operated by an explosion directly within the cylinder, between the head and the piston, the explosive agent being a highly compressed mixture of air with one of the hydro-carbon compounds, such as natural or city gas, naphtha, gasolene, kerosene, crude petroleum, benzine or alcohol. This explosion generates a gas which forces the piston outward. The term "gas engine" is, perhaps, the most expressive, being correct and of similar form to "steam engine."

The steam engine in its most modern and perfect form is double-acting, that is, the two ends of the cylinder are tightly closed and the steam is admitted to each in alternation, the other meanwhile being connected with the exhaust, the piston being driven positively back and forth. This form of construction necessitates the employment of a piston-rod rigidly connected to the piston head and moving at all times in an absolutely straight line, to maintain which a sliding block moving between fixed guides, and known as crosshead, is necessary. The connection between the piston and the crank is by means of a connecting-rod, one end coupled onto the crank-pin, while the other oscillates on the wrist-pin of the crosshead.

The gas engine, at least in all its common forms, is essentially single-acting, the piston being driven in only one direction by the direct force of the gas, the return stroke being an idle one, due to the momentum of the fly-wheel. This being the case, a much simpler form of construction is admissible, and a return has been made to the old "trunk" engines, famous in marine work in the side-wheelers of half a century ago. In this type of engine one end of the cylinder is open, and the piston, instead of being a comparatively thin, flat disc, is in the form of a long cylinder, also with one end open. The relatively great length of the piston itself keeps it true in the cylinder with no aid from the piston-rod; and this latter, instead of being rigidly fitted and fastened, is journalled on a wrist-pin through the piston near the closed end or head. The guides, crosshead, and connecting-rod are dispensed with, and the piston-rod itself is journalled on the crank-pin. It will be seen that the form is more compact, the total length from cylinder head to crank-shaft being shorter by almost the length of the connecting-rod, and there is actually saved the weight of one cylinder head with its stuffing box, part of the housings or supports, and the guides, crosshead, and connecting-rod. On the other hand, a heavier fly-wheel is required, and the power is less for a given



THREE-CYLINDER FOUR-CYCLE MARINE GASOLINE ENGINES FROM 30 TO 75 H. P., BUILT BY MESSRS. FAIRBANKS, MORSE & CO., CHICAGO

size and weight of cylinder. As the pressure on wrist-pin, piston-rod brasses, and crank-pin is always in one direction, the brasses may be loose, and there is no necessity for the accurate fitting that is essential in the double-acting engine.

While all gas engines are of the general construction thus indicated, they are further subdivided into two distinct types, each involving different principles of operation. The names given to these types in common practice, "two-cycle" and "four-cycle," are, unfortunately, calculated to mislead the novice at the start, and it is well to bear in mind that the true meaning of these terms is a two-stroke cycle and a four-stroke cycle; in other words, two separate strokes are needed to complete the cycle or series of the former, while four strokes are required for the latter.

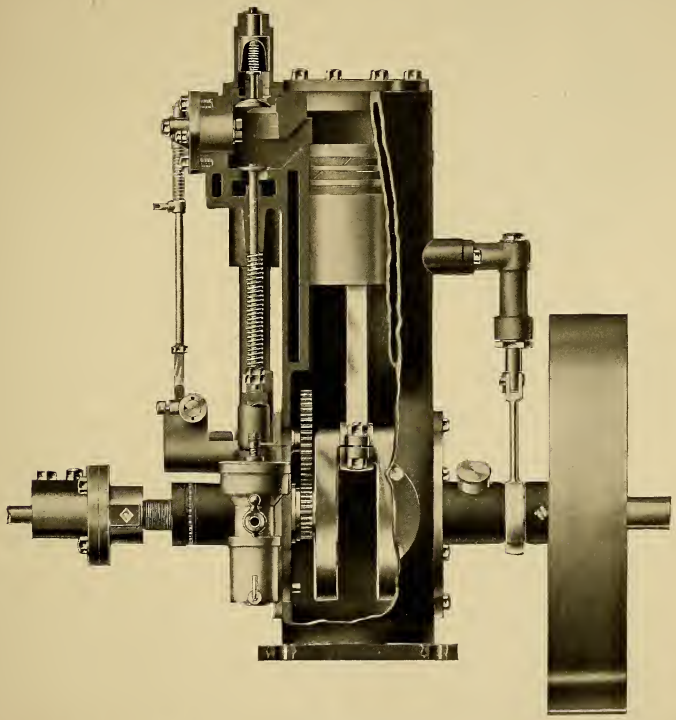
The "cycle" of the steam engine is made up of two separate operations, the admission and expansion of the steam, driving the piston one way, and the exhaust, as the piston is forced back on the return stroke. The corresponding series of movements for the gas engine is as follows:—Admission of gas to the cylinder of the engine; compression of the gas to the ignition point as the piston moves upward; explosion and expansion of the gas, driving the piston downward; and finally, expulsion of the combustion gases so as to be in readiness for a new charge. In this explanation the writer refers to a vertical design; hence the designation of "up" and "down" stroke of the piston. The action in a horizontal engine, however, is exactly the same.

Taking, first, the "four-cycle" type as the more simple of the two, it may be repeated that four strokes of the piston, or two complete revolutions of the crank and fly-wheel, are necessary to complete the full series. Starting with the piston at its highest point, and the space just above it empty, as it moves downward through the impulse of the fly-wheel, a partial vacuum is created, a valve in the head of the cylinder opens, and a mixture of air and gas rushes in to fill the space. After reaching the bottom of the cylinder the piston, still in obedience to the fly-wheel, begins to rise, compressing the gas, the inlet valve closing as soon as it feels the pressure on its inner side. By the time that the piston reaches the top of the cylinder the full volume of the cylinder is compressed into the small space at the head known as the combustion chamber.

When the maximum point of com-

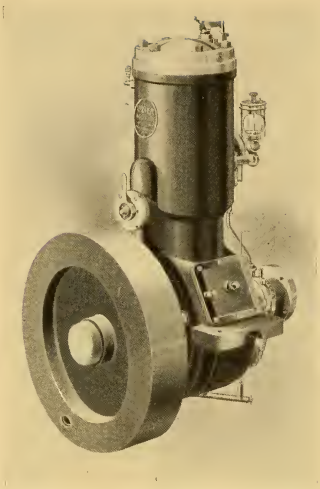
pression is reached, the charge is fired by an electric spark or other means, the gas explodes instantly with a great increase of volume, and the piston is driven rapidly to the bottom of the cylinder, giving a powerful impulse to the fly-wheel. As the piston reaches the end of this working stroke, the gas having free for the introduction of a fresh charge as the piston descends in beginning a new cycle.

In the two-cycle motor these same operations are condensed into the compass of only two strokes of the piston, or a single revolution, every downward stroke being a working one, during



A FOUR-CYCLE MOTOR MADE BY THE CHARLES A. STRELINGER COMPANY, DETROIT, MICHIGAN. THE EXHAUST VALVE IS POSITIVELY OPERATED BY GEARING AS SHOWN, LIFTING ONCE IN EVERY FOUR STROKES

expended its power, a second valve, communicating with the exhaust pipe, is opened; the piston rises under the impulse of the fly-wheel and pushes before it the waste of soot, burnt gas and the balance of the charge, if any, which has escaped ignition, leaving the cylinder which the exploded gas drives the piston and then escapes of itself from the cylinder, while on the up-stroke a new charge is taken in, compressed, and finally exploded. To accomplish this a different arrangement of the ports is necessary. In the four-cycle motor both



A TWO-CYCLE MOTOR MADE BY THE LOZIER MOTOR COMPANY, PLATTSBURG, NEW YORK.

ports are in, or closely adjacent to, the head of the cylinder; while in the two-cycle type the inlet port is placed in the walls of the cylinder just at the end of the stroke, the exhaust port being a little higher up and on the opposite side. There are no individual valves, as in the four-cycle engine; but the piston, passing over the ports, acts as a valve in opening and closing the apertures.

When the piston is at the top the compressed charge is exploded and the piston is forced downward; as it nears the end of the stroke it uncovers the exhaust port and opens a means of egress to the burned gases; a moment later it begins to open the inlet port on the opposite side, allowing the fresh charge to enter. The theory is that this charge, rushing in under pressure, will drive out all the waste, completely "scavenging" the cylinder in a moment, and to aid in this work a small metal shield, called a baffle plate or deflector, is attached to the piston just opposite the inlet valve to force the entering gas to take an upward course instead of crossing direct and escaping through the exhaust port.

As the piston starts upward, the first movement is to close the inlet port, beginning the compression of the charge, the exhaust port remaining open for a brief interval, and, in theory, allowing the last of the spent gases to escape. As soon as this port is covered, the charge is fully enclosed and compression continues as the piston rises until, just at the top of the stroke, the charge is fired and a new cycle begins.

It is not intended here to enter into the arguments for and against the two types, but simply to describe the inherent differences of construction. In the four-cycle type the supply pipe leads to an inlet valve opening inward under pressure and held to its seat by a spiral spring. As a rule, all the valves of a gas engine are of mushroom shape,—a wide, flat head with a long stem to steady the valve on its seat. In some cases the inlet valve is automatic, opening under the suction of the descending piston; in others it is operated directly by mechanism; the latter, the "mechanically operated" valve, is generally used on marine motors, and, of late, has come forward very prominently in motor car work. The exhaust valve is of similar construction, but is held to its seat against the suction by a stronger spring, and, when the time comes, is opened by a cam working against the foot of its stem, which is much longer than that of the inlet valve.

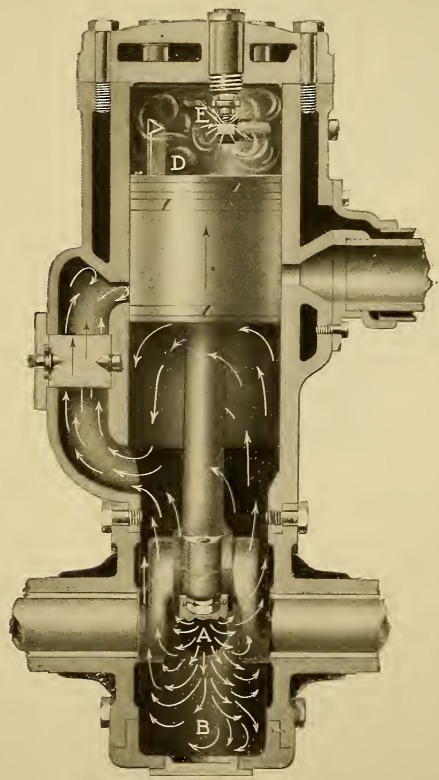
To operate one or both of these valves, some auxiliary gear is necessary, a "half-time shaft," driven by spur or helical gearing from the main shaft and making one revolution to two of the latter, or operating each valve once in every four strokes. Cams on this shaft act on the valve stems, and other cams act on the rods of the ignition device.

In the two-cycle type there must be an auxiliary reservoir for the pre-compression of the gas, the usual custom being to make the crank case and base of the engine gas-tight. The only valve is a check valve on the gas supply pipe opening into this base; as the piston rises, a vacuum is produced in the closed base and gas enters through the check valve; as the piston descends, the check

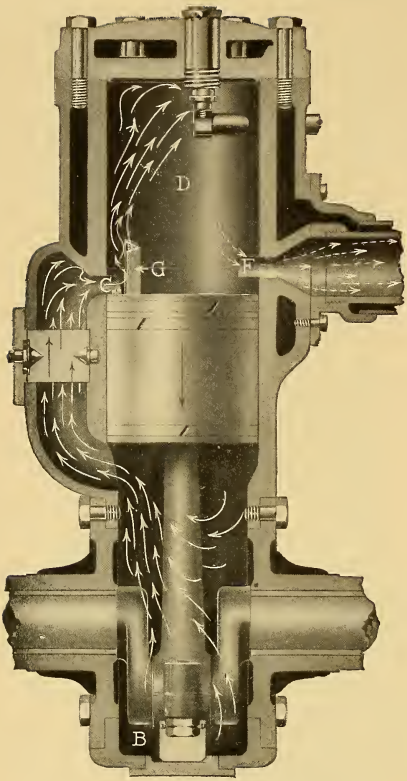
valve closes, while the inlet port is covered by the piston, the charge is compressed in the crank chamber, and then as soon as the inlet port is uncovered, the charge rushes upward through a passage in the cylinder walls and into the cylinder above the piston. Here no valves are necessary, except the automatic check valve; but there must be some auxiliary mechanism to operate the igniter.

The broad principles of the two types being thus outlined, in order to understand the various auxiliary parts it will be well to start at the fuel tank, presumably filled with gasoline. This tank, in a launch, will be located as far forward or aft as possible, or at some convenient point under the floor,—in any case, remote from the motor. It may be placed above the level of the vapouriser, feeding by gravity, or below with a feed pump from the engine. Following up the length of stout copper or lead pipe from the tank there is found near the base of the engine the vapouriser, atomiser, carburettor, or mixing-valve, of varied design, but all embodying the same general principle. A comparatively large volume of air, first warmed by passing close to a heated pipe, is drawn into a reservoir, roughly of the size of a large teacup, while a small amount of gasoline is admitted in such a way as to break up the stream and subject its many minute particles to the action of the air current, the proportion being about one of gasoline to eight of air. The gas thus formed passes on through a throttle valve to the crank chamber in the case of a two-cycle motor, and to the inlet valve in the four-cycle. Once enclosed in the cylinder, this charge is compressed by the piston, becoming highly inflammable.

The ignition of the charge may be accomplished by two means, the incandescent tube, as in the older motors, or the electric spark, as now used on practically all launch and motor car engines. The spark may be generated by a primary battery or a sparking dynamo, or magneto, a very common practice being to use the primary battery for starting the motor, and, when it is in operation, throwing in a dynamo driven by a belt or by a friction wheel from the engine flywheel. On leaving the cylinder the exhaust gases are highly heated, and move at a velocity which would make a very



A LOZIER TWO CYCLE ENGINE SECTION. ON THE UPSTROKE OF THE PISTON, A CHARGE OF VAPOURISED GASOLINE IS DRAWN FROM THE VAPOURISER INLET *A* INTO THE ENCLOSED CRANK CASE *B*



ON THE DOWNWARD STROKE THE VAPOUR IS SLIGHTLY COMPRESSED IN THE CHAMBER *B*, AND, AT THE COMPLETION OF THAT STROKE, ESCAPES THROUGH THE THEN UNCOVERED PORT *C* INTO THE UPPER CYLINDER END *D*. THERE THE VAPOUR IS FURTHER COMPRESSED BY THE SUCCEEDING UP-STROKE OF THE PISTON, AND IS THEN IGNITED ELECTRICALLY AT *E*. SEE CUT, PAGE 299

annoying noise if discharged directly into the open air. Instead of this they first pass to a "muffler," an enlargement of the exhaust pipe, where a part of their heat is utilised in warming the fresh air supply on its way to the carburettor. In the muffler, which is a cylinder of some size compared with the pipe, the gases are allowed to expand, and their momentum is checked by obstructions in the form of plates with holes or some similar arrangement, so that on their final exit beneath the counter of the launch, possibly below the water, they produce very little noise.

A very essential feature of every gas engine is the cooling system by which the temperature of the cylinder is kept sufficiently low to permit the use of a suitable lubricating oil and to prevent undue expansion of the moving parts. In all marine motors the cylinder, at least, and often the heads as well, are water-jacketed, the cylinder walls being made double, leaving a space for the passage of water. A small pump driven from the engine draws water from without the hull and forces it through the water-jacket, thus cooling the cylinder walls, valve chamber, and head, after which it is discharged outboard. Any obstruction of the circulating water must ultimately result in the stoppage of the engine.

With much to recommend it, the gas engine has two weak points, which will be best understood by a comparison with the steam engine. The latter, as is well known, may be run equally well at any speed, the highest or the lowest, a wide range of variation being possible through the manipulation of the throttle valve in the pipe which carries the steam from the boiler to the engine. At the same time, the engine may be run equally well in either direction by means of the valve motion. The gas engine, on the other hand, lacks this flexibility of the steam engine, and, in a general way, it gives the best results, in point of economy and efficiency, at some one speed for which its parts have been specially designed. In addition to this, while the two-cycle motor may actually be reversed by proper manipulation, as a practical fact the gas motor of either type must always run in one direction. In the motor car this lack of "flexibility" and of ability to reverse has led to the adoption of costly and complicated systems of change-speed gears, giving three or four speeds forward and one backward. In the launch the lack of "flexibility" or variation of speed is of

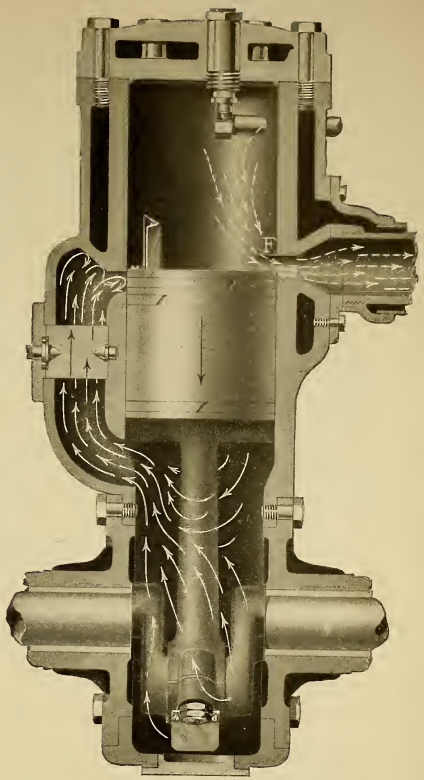
less importance, but quick backing power is most essential.

On the former point it must be said that of late great progress has been made in perfecting the speed control system of the gas engine by means of altering the quality of the mixture in its proportions of oil vapour and air; the quantity admitted, by means of the throttle; and the time of ignition, by means of mechanical details in the sparking apparatus. In addition, very efficient automatic governors are now used, so that in practice a sufficiently wide range of speed is obtained.

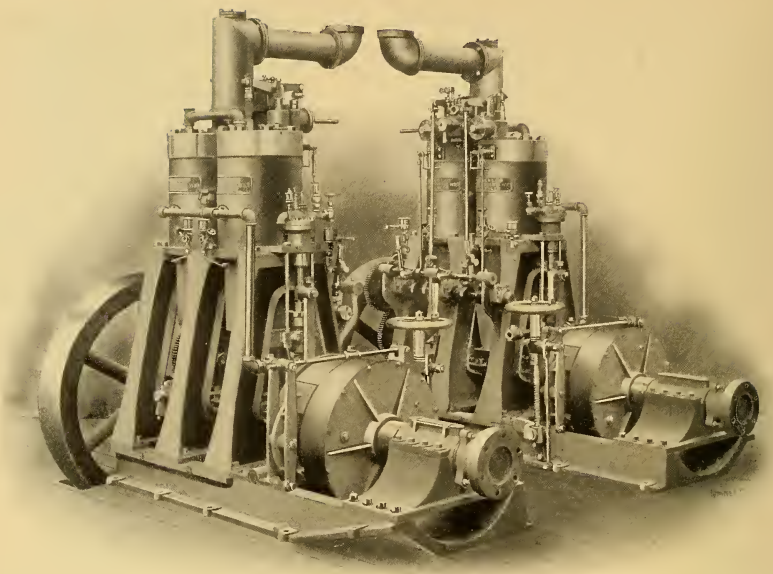
When it comes to reversing, one of two means must be employed,—a clutch and gears in the propeller shaft, or a reversing propeller. In the former case the propeller shaft is separate from the crankshaft, the two being connected at will by a friction clutch, bevel or spur gears being employed to give the backing motion. By means of a lever the clutch may be thrown off entirely, allowing the engine to run without the propeller, or the latter may be driven with the engine in either direction.

In the reversing wheel the propeller shaft is solidly coupled to the crankshaft, but this is double, the shaft proper carrying a sleeve or tube for its full length. The blades are made separate from the hub and pivoted in it so as to turn freely, their movement being controlled by a rack and pinion or similar device actuated by means of the sleeve on the shaft. The blades, two or three in number, may be set to drive the launch forward or astern, or may be "feathered" so as to keep it motionless, while the pitch of the wheel may be altered at will when the engine is running. The reversing gear is used in launches from 30 feet upward, but in the smaller craft the reversing wheel is commonly employed.

The gas engine is in many ways excellently adapted for marine use; it is self-contained, with no boiler of any kind and no fire; it is compact in dimensions, and, through the trunk piston and the absence of the connecting-rod, its centre of gravity is very low. The engine proper may be of light weight, recent refinements in motor car practice having done much to reduce the weight of all parts; the fly-wheel, in both the two-cycle and four-cycle type, is necessarily comparatively heavy, but it is very low in the boat, just clear of the keelson. The engine is light enough to permit it to be placed in the extreme end of the hull if desirable, and the fuel tanks may be located in any convenient place, with only a small pipe to connect them with the engine. Only one man is required to run the engine, and all that is needed on his part is care and intelligent supervision, there being no continuous manual



AFTER IGNITION AND EXPLOSION THE PISTON IS FORCED DOWNWARD AND THE BURNT GASES ESCAPE THROUGH THE PORT *F*, WHICH IS UNCOVERED AT THE END OF THE STROKE



TWIN GASOLINE ENGINES OF 65 H. P. PHOTOGRAPHED IN THE POSITION THEY OCCUPY IN THE TUGBOAT "W. P. FULLER," ON SAN FRANCISCO BAY. THE BOAT IS 80 FEET LONG, 20 FEET BEAM, AND UNDER ORDINARY CONDITIONS MAKES FROM 10 TO 12 KNOTS AN HOUR. THE ENGINES WERE BUILT BY THE HERCULES GAS ENGINE WORKS, OF SAN FRANCISCO, CAL., FOR WHICH THE LEEDS MARINE EQUIPMENT COMPANY, OF BRIDGEPORT, CONN., ARE THE EASTERN AGENTS

labour, such as is involved in firing a steam boiler. The engine may be started at a moment's notice, and when not in use there are no heated furnace and boiler to make the boat uncomfortable for hours afterwards.

The smallest size of motor is fitted for a 10-foot yacht dinghy; the largest at the present time will drive a heavy coasting schooner of several hundred tons, and the limit of size is constantly increasing as builders gain in experience and as the demand grows.

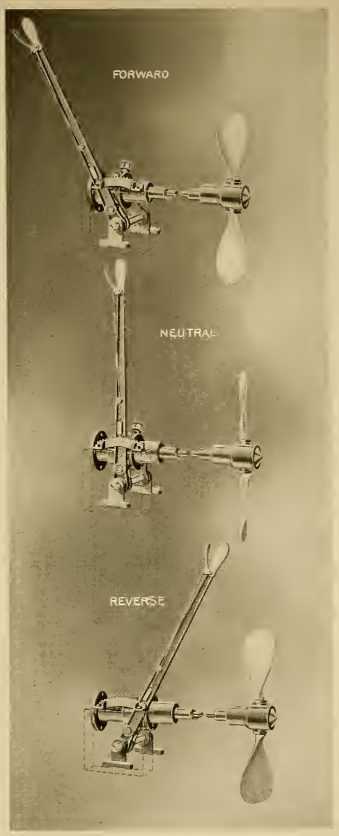
Up to the present time the principal fuel of the gas engine for marine use has been ordinary gasoline, its cheapness and the ease with which it can be purchased even in remote localities being greatly in its favour. The great objection to it is its volatile nature and the highly explosive quality of its vapour, making it highly dangerous in a free state, as when spilled in filling or on leaking from a tank. The manifest superiority of kerosene in point of safety and of the ordinary crude petroleum in point of cost have led to innumerable attempts to employ them in the place of gasoline. In the case of kerosene some degree of success has already been attained, and last year a 38-foot launch, fitted with a kerosene motor, made the voyage from New York to Falmouth, England, in thirty-six days, using 440 gallons of kerosene. The serious difficulty with kerosene and the heavier oils is the deposit of carbon, fouling the cylinders and obstructing the passages. When this has been overcome, the use of the gas engine will be still further extended. In France and Germany a satisfactory substitute for gasoline has

been found in alcohol distilled from beets, potatoes, and other agricultural products, the manufacture of this fuel being strongly fostered by the efforts of the government. The alcohol thus produced is cheap, and though it must be enriched by the addition of benzolene or some other form of petroleum, it compares favourably in both cost and efficiency with gasoline.

The three powers in use at the present time for the propulsion of launches and small craft are the steam engine, the gas engine using gasoline and kerosene, and the electric motor. The steam engine, as already shown, is very unsuitable for small craft; but in launches of 75 feet and upward its disadvantages become less serious, and it possesses great advantages in its established reliability and certainty of action and its flexibility. The development of the motor car has, of late years, worked wonders in the improvement of the smaller steam plants, and where steam is for any reason desired in a small launch, very good results may be obtained with the automobile engine, in itself a miniature marine engine, and the small, light and powerful automobile boiler with its drawn-steel shell and numerous small copper tubes, fired by gasoline or kerosene.

In the ordinary yachting practice of the day the line between the steam engine and the gas engine appears at about 75 feet; launches below this size use the latter, while the older power is still found in most larger craft. At the same time, this line is changing every day, as greater perfection is attained by the builders of the gas engine, so that it is impossible to foretell its final limit as compared with steam.

Within its rather narrow radius of application the ideal power for launch propulsion is the electric motor,—simple, compact, and powerful, installed under the floor or in space otherwise useless, and free from dirt, smell, and danger of explosion. Unfortunately, it is dependent for its power on the secondary battery, a weighty affair and capable of furnishing power for only a comparatively limited distance, forty or fifty miles at most. When used within the former radius and with proper facilities for charging, the electric launch is the ideal craft, especially for ordinary pleasure running. It is clean, comfortable, fast, and it may be kept ready for use at an instant's notice. These



A LOZIER REVERSIBLE PROPELLER CAN BE MADE EITHER A RIGHT-HAND OR A LEFT-HAND SCREW WHILE THE ENGINE IS RUNNING THROUGH THE USE OF A CONVENIENTLY LOCATED REVERSING LEVER. WHEN IN A CENTRAL POSITION, THE PROPELLER BLADES STAND AT RIGHT ANGLES TO THE SHAFT AND OFFER NO RESISTANCE TO THE WATER

ONE OF THE ELECTRICALLY DRIVEN LAUNCHES OF THE ELECTRIC LAUNCH COMPANY, OF BAYONNE, N. J.

launches first came into general prominence at the World's Fair in Chicago in 1893, where they were used with success for the conveyance of passengers about the waters of the Fair grounds. Since then they have become common on many lakes and rivers as regular appurtenances of summer hotels and cottages. The electric launch is also in general use as a yacht tender, there being facilities generally at hand on the yacht for recharging the batteries. While no limit is in sight to the possibilities of improvement in the storage battery, and advances are also probable in the primary battery, the electric launch will probably always be limited to a comparatively small radius of operation beside that of such independent powers as the steam and the gas engine.

NATURAL SOURCES OF ENERGY

THE PROBABLE EXTENSIVE DEVELOPMENT OF SOLAR POWER

By Dr. Louis Bell

MUCH has been written during the last decade concerning the failure of the earth's fuel supply and the vision of frigid despair that lurks behind the portals of the not distant future. True enough, we of the present day have used our supplies like reckless vandals, avaricious and purblind, robbing our children and our children's children without scruple. There is no stopping the greedy hordes in their frantic money hunt, and it is the part of wisdom to cast about for means of saving from the general disaster as much as possible.

The case really is not quite so bad as it looks, but at the best it is bad enough. The present coal supply of the world will, at the present quickening pace, last perhaps a few hundred years with the aid of such new mines as may turn up in out-of-the-way places; but once gone, it will be gone forever, and the paltry wood supply which is renewed year by year cannot give material help.

The supply of good and easily available coal is even now showing us the beginning of the end, and the American anthracite strike last year proved how small a shortage in the normal coal supply may cause widespread distress. Deep mining and heavy transportation charges mean costly fuel long before the total supply nears its end, and it is not too much to say that from the present time on we must expect to see the price of fuel on a pretty steady and steep upward gradient. The ultimate outcome is a case rather for speculation than for prophecy. That men and nations will put up a strong fight against the inevitable is obvious, but ultimate defeat is certain. We are drawing, without thought for the morrow, on a store which is plainly limited.

But even so, the case is not a desperate one for humanity if viewed philosophically. In the last resort the fight before us is not for civilisation, as such; but merely for the preservation of the *status quo*. Compared with the present consumption of coal, for example, the fuel used in the golden age of Athens is an evanescent quantity. Civilisation does not consist entirely of tall chimneys and automatic machinery, but we naturally wish to preserve these, together with the rest. Nor are manufactures the sole source of happiness and wealth; but we would fain save them, among other things, from the penalty of unthinking avarice. If worst came to worst, men could migrate, as they have in case of need ever since the dawn of time, seeking in this instance a climate where there would be small need of fuel. Cities and empires are really but flickering shadows on the clouds of space.

"They say the Lion and the Lizard keep
The courts where Jamshyd gloried and drank deep."

London and Paris and New York have no better guarantee of permanence than had Persepolis, and when the northern land becomes untenable for lack of fuel, men will build anew elsewhere.

The practical problem that presents itself to the student of economics is, first, how to make the most of the fuel that remains; and second, how to supplement it so as to most increase the area of the earth's surface which will remain tenable when the fuel supply fails. The

first end is to be reached by deliberate and persistent efforts to increase the efficiency with which fuel is utilised. Until recently fuel has been so cheap that the stimulus to economy was far from acute; but from now on the reward of economy will progressively increase.

Already much has been accomplished, for the power derived to-day from a pound of coal is nearly three times as great as it was fifty or sixty years ago. But in spite of this the inroads into the coal measures are yearly heavier, and further success in this line of economy will be more and more difficult Perhaps the best promise at present comes from the gas engine, which can be made to double the present efficiency of steam engines; but even this gain will serve only to delay the end a little. The generation and distribution of electric power from plants of enormous capacity and great efficiency will afford great help by enabling mankind to utilise to advantage fuel now hardly worth transportation, and much of this work is likely to be done within the next few decades.

Still greater saving can be accomplished by a thorough revision of current methods of heating. The ordinary means of heating buildings are uneconomical to the last degree, and it is not too much to say that their efficiency can be doubled by close attention to conditions and by more skillful methods of constructing buildings. We have already reached the pass where of two methods of obtaining power and heat, of equal total cost, but one involving more fixed charges and the other more fuel expense, the former should be unhesitatingly chosen. Parity of cost this year means a saving a few years hence when coal will be higher than at present.

In spite of every effort of this sort, there remains the irrevocable fact that we are consuming our capital, and that at a rate which has steadily increased, in spite of former improvements, and will continue so to do. Hence, it is necessary to seek out whatever means can be found for obtaining power and heat as such from sources that do not involve further demands on coal.

Obviously the first recourse is to water-power in the ordinary form, and how successfully it has been taken is a matter that needs little comment. Falls like Niagara, good for at least three or four million horse-power, are magnificent sources of power; but they are quite insignificant features of the world's aggregate water-power. The bulk of it is in small falls, giving a few hundred or a few thousand horse-power each. Every one of these, properly utilised, stops a call for fuel, and in favoured districts it is even now quite feasible to remove the whole region from our present discussion.

But as a matter of fact, all the electrical transmission yet accomplished is only a drop in the bucket. If all that has been done in the past decade were crowded into a single year's development, it would not noticeably check the steady increase in the demand for coal even for that single season. Comparatively few power transmissions supersede the use of fuel; they go rather to building up new industries and supplying new luxuries, and they cut as yet but a small figure even in this rôle. Even with the rapid present increase in electrical work there is little prospect that hydraulic development will materially check the demand for coal, let alone reducing it.

Nothing but the dire stress of rising price of fuel will force enough capital into hydraulic plants to produce a perceptible effect. And while there is in the aggregate enough water-power in some places to set coal a-begging, most of it is in such locations and in so small units that its utilisation would mean a complete rearrangement of social and industrial tendencies.

Moreover, at the present rate of forest destruction, the complete denudation of vast tracts of country is a matter of comparatively few years, so that the available water-power will be greatly lessened. The effect of such destruction is already beginning to be felt on a growing number of streams, and one only has to look at Southern California to realise the ultimate outcome in enormous variations of flow that make full utilisation of the streams very difficult. It is not easy to get exact data on the effect of

denudation on the variations of stream flow; but it is probably within bounds to say that with a given drainage area and rainfall, the practical capacity of a stream in available power would be lessened 50 per cent. by the complete denudation of the watershed.

The practical aspect of the water-power question, then, is that while the aggregate amount available is enough to supply fully all present and many future demands for power, present industrial growth is so rapid and is so thoroughly grounded in laws that ignore the fuel question, that hydraulic power is at present of very little importance as an auxiliary. It can, and will, become of great importance as the fuel stress gets more severe; but it will involve very great changes in the distribution of capital and population, even with all the aid that long-distance electrical transmission can give.

In order to preserve the *status quo* it is not sufficient merely to replace the use of fuel for power purposes, but to find means of keeping down its expenditure for heating purposes. This is a far more difficult matter than the former, for it portends an inefficient cycle of operations. The transformations of energy that lead to mechanical power are, in case of heat engines, conspicuously inefficient; and if the power so derived be converted back to heat, the total losses are very great.

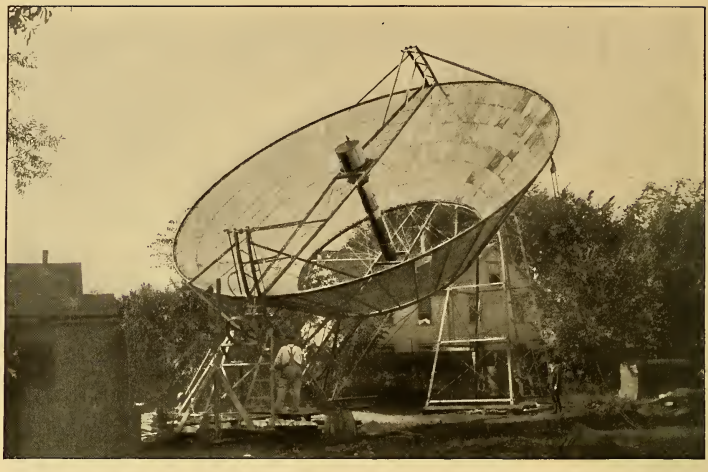
Hydraulic plants, worked on a very large scale, can be made to accomplish electrical heating at a price comparable with coal at prices not greatly in excess of those now ruling; but this branch of work has been barely touched up to the present time. The inevitable result of scarce fuel will be to increase it, but at the cost of throwing enormous extra work on existing water-powers, and the steady tendency must be to cause emigration to regions where less artificial heat is needed than at the present centres of the world's activity, and to concentrate the new civilisation in such of these regions as are supplied with natural sources of energy.

Of such sources, aside from water falls, the only ones available are tides, wind, and solar radiation. The first mentioned have been utilised in a very small way; their larger use has been considered dubious. In the first place, tides of a height readily available are local in their occurrence; and, second, tides are essentially periodic, so that their direct power is available only in two short daily periods occurring in cyclic order during each part of the twenty-four hours as the month is rounded out. Hence the first problem of tide utilisation is storage of power.

It is possible by the use of multiple reservoirs to extend the use of the tides throughout the twenty-four hours. A three-pond system accomplishes this end at considerable cost in complication of waterways and variations in head, and even a two-pond system helps to a steady use of tidal power for part of the day. There is, too, great variation in the rate of flow in the tides in different localities, the most favourable case being that in which the tide rises and falls most rapidly. But the main trouble with the tides is that the total rise and fall is relatively small, compelling one to deal with low, as well as variable heads, and to provide enormous reservoirs to store even enough water for use in two daily five-hour runs. In very few places would it be possible to rely on more than 6 feet mean working head.

This means that if the storage pond were 6 feet deep, each square mile of reservoir would store water for about 5000 H. P. for a five-hour run. Even this is an unusually favourable case, and it is evident at once that hydraulic works on this scale imply a very large investment for the power obtained.

The only tidal powers to be taken seriously as able to count in large work are such as exist in exceptional spots, like the Bay of Fundy, where the tides run 40 feet high under normal conditions. There it should be possible to obtain, for two five-hour runs, more than 50,000 H. P. per square mile of reservoir. It may seem fanciful to consider the utilisation of this power, and so it is with coal at its present price. But with steam coal at $20 (£4) a ton or more, as it may well be within the



A 10 H. P. SOLAR BOILER AT SOUTH PASADENA, CALIFORNIA. THE BOILER CONSISTS OF ONE-INCH COPPER PIPE, BLACKENED, ARRANGED IN A 14-INCH DIAMETER SPIRAL THE BOILER PRESSURE IS 200 LBS. PER SQUARE INCH. THE MIRROR CONTAINS 1000 SQUARE FEET OF SURFACE

experience of some even now living, the case will stand very differently. If one stops to consider the effect on human industries of coal at such a price, it is evident enough that desperate remedies would be in order.

A glance at a map will show that the inner extremity of the Bay of Fundy is almost a tidal lake, known as the Basin of Minas. At its outlet rise two great headlands, less than three miles apart, while the narrower tide-race between them takes the full current for the basin within. This covers an area of more than 400 square miles, so that it is safe to say that through that narrow gap more than 200,000,000 H. P.-hours run daily to waste. To utilise it would require an engineering feat more tremendous than anything yet attempted by man, but in years to come the game may be worth the candle.

Using tidal power implies either intermittent power supply or storage. The latter is not at all an impossible alternative even with the means now at hand. For example, let us take a tidal power yielding 100,000 H. P. in two five-hour intervals. To deliver continuous ten-hour power, a storage battery would be required having a capacity of about 350,000 kilowatt-hours. This could be put up probably for about $3,500,000 (£700,000), on which, reckoning interest and upkeep at 10 per cent., the annual charge would be $350,000 (£70,000). Such a plant could probably sell its full output, and the charge per year due to storage is evi dently only a small sum, quite possible under the assumed conditions, even considering the probability that the price of material would rise considerably under the condition of greatly increased cost of fuel.

The writer, however, inclines to the opinion that when the fuel stress gets so severe as to call for the utilisation of tidal and other difficult hydraulic powers, industry and population will tend to drift southward to a more genial climate where the struggle against Nature will be on easier terms.

The utilisation of wind-power is even less attractive than that of tidal-power, since the supply is a very erratic variable, save in the region of the trade winds. Wind-power in a small way is

a great convenience, but it cuts only a small figure as a protection to the fuel supply in general. The largest windmills are of only a few horse-power, and run at so variable a speed that, except for purposes like pumping, they are decidedly inconvenient. Still they have their uses as adjuncts in a general scheme of power supply.

There have been propositions to erect batteries of windmills driving dynamos and to so concentrate their power by storage as to obtain a continuous and considerable supply. Doubtless this could be done, but hardly to advantage, except in localities where the wind blows fresh and true, with some approximation to regularity. Along the sea coast in certain regions these conditions exist, although seldom to an extent warranting much reliance on wind-power.

As compared with transmitted hydraulic power, the utilisation of wind has little to commend it, for it is relatively costly and inconvenient. Like the earth's internal heat, there is plenty of it as a whole, but little that can be put to good use.

There remains as a possible recourse the enormous energy received from solar radiation. Although this is the great ultimate fountain of terrestrial energy, it is not altogether easy to utilise directly. The total amount of radiant energy received by the earth may be roughly reckoned at the equivalent of no less than 10,000 H.P. per acre, obviously more than enough to satisfy the extreme requirements of industry.

John Ericsson was the first engineer to take up seriously as a practical problem the task of utilising this enormous store. With his customary dogged persistence he did not rest until he had produced a solar engine that would do serious work. The result he attained was the production of one horse-power per hundred square feet of exposed normal reflector surface,—a figure that has since been reached by other investigators, and which may, therefore, be taken as a safe basis of reckoning.

The method used by Ericsson, and by those who have followed him, was to concentrate the solar rays upon the boiler of an engine by means of a huge concave mirror, thus compelling the sun to furnish the fuel and serve as stoker. And the process worked well, both with the great inventor's hot air engine and with the ordinary steam engine. Clearly such a mirror, containing one or several hundred square feet of surface, could not economically or conveniently be made of a single sheet of glass, and as a matter of practice it has been found best to build up the reflector of plain strips of silvered glass, individually set in an appropriate framework. These strips do not bring the rays to an exact focus, but still easily concentrate them all on an object the size of the boiler employed. The composite mirror must evidently move so as to follow the sun in its daily course, and this is easily accomplished by clockwork.

A recent practical type of such apparatus is shown on the opposite page. It consists primarily of a mirror structure forming the frustum of a short, hollow cone with its base turned sunwards. The cone is lined with strips of silvered glass, perhaps 2 feet long and 6 or 8 inches wide, set in a light steel framework by means of bolts and soft washers. The frame is supported between two skeleton piers on a polar axis capable of being moved in declination along the arcs shown projecting a little above the mirror, so as to follow the seasonal changes in the sun's altitude. This adjustment is readily made by hand every few days as required.

The diurnal motion is given by clockwork. This is not continuous, as in clock-driven telescopes, but by steps every minute or two, the driving mechanism being locked during the intervals to reduce the danger of vibration from wind.

The boiler is a coiled water-tube affair of 1-inch blackened copper pipe, equipped with a superheater and placed axially in the centre of the mirror. In the particular example shown, the mirror is 36 feet in diameter, and contains about 1,000 square feet of silvered surface. The boiler carries 200 pounds pressure in full sunshine and is good for 10 H. P. Flexible couplings enable the

steam to be readily led to the engine. The whole structure can be stripped, "knocked down," and put together in any sort of out-of-the-way place with no tool beyond a monkey wrench. There are no very heavy parts, so that the problem of transportation in a difficult country is comparatively simple.

The absorption of solar heat by the atmosphere is so great that when the sun is near the horizon such apparatus cannot be worked at full power, but in clear sunshine it is fully available for at least eight hours a day. Getting up steam after the sun is fairly at work is about an hour's task, and then the engine will drive steadily on until the approach of sunset.

Obviously a machine of this description, however excellent, cannot be used for general power purposes with good results, except in regions where there is reasonably steady sunshine. In the world's several arid districts, for example, such as what was formerly known as the Great American Desert, solar power is of consequence. In these a solar engine could be used nearly or quite 300 days per year, while cloudiness for more than a single day at a time would be quite unusual, as during the so-called rainy season many of the showers occur during the night. For irrigation work and other discontinuous employment sun power could, therefore, be freely used, and at a cost generally less than that of power generated by fuel.

The cost of power so obtained from sunlight is merely the cost of attendance and minor supplies plus the charge for investment and up-keep. The fixed charges, assuming a 10 H. P. unit like that shown on page 308, should not exceed, say, $3 (12s.) per month per H. P., and the attendance would amount perhaps to $4 or $5 per H. P. (16 to 20s) more, so that the total annual expense would be, perhaps, $75 (£15) per H. P. per year, or about 3 cents (1½d.) per H. P.-hour, based on eight working hours per day.

This is considerably below the cost of power obtained from small steam or oil engines, and compares favourably with the prices commonly charged for electric power in small units where electric power is available. In operating two or more solar generators together, the attendance charge would be materially reduced. Single generators much larger than that described would be somewhat unwieldy, but two or more could readily be connected to a single engine or pump.

Sun-power is, therefore, readily available over very large areas in units of moderate size; but if the demand be for a general power supply, the case is less easy. Of course, solar engines could be used to drive dynamos from which power could be stored for continuous use; but about 30 per cent. of the energy would be lost in the extra transformations. In spite of this, sun-power must be regarded as even now practicable on a considerable scale within the favoured areas.

There is a huge arid area in Northern Africa which could be thus utilised for industries requiring power, as Ericsson pointed out years ago. He estimated that the enormous amount of nearly 10,000,000 square miles of the earth's surface was available for solar power, and experience has shown that nearly all this semi-desert region can be reclaimed by irrigation,—space enough to support the whole of the earth's present population.

Without indulging in speculation of this sort, it is reasonably certain that very large areas, now sparsely populated, can be made available and furnished with all necessary power by utilising the sun's rays, together with what water-power may exist.

It must be remembered that, if need be, solar heat can be made directly available for cooking, so as to render fuel for this purpose quite unnecessary, except as an occasional auxiliary. Even this minor use could be averted by a very moderate amount of electrical energy stored from solar engines. A few years ago very successful experiments were made in India on cooking by sun-power, and it is beyond question that the thing is not only feasible, but quite easy of accomplishment. Imagine an apparatus on the general plan of the one shown on page 308, but much smaller and with cooking compartments

in place of the boiler, and solar cooking becomes a simple matter. It might be a bit difficult to arrange for frying in this way, but that would be reckoned by many as a positive advantage.

Incidentally, it should be mentioned that even now solar heat is being utilised for heating water for various household purposes. The apparatus for this purpose is absurdly simple, merely a sectional boiler of thin blackened copper, exposed on the sunny side of the roof under a glass cover very like a hot-house frame, and suitably piped for supply and demand. An hour's exposure to full sunlight raises the water to a temperature from 30° to 60° F. above that of the air, and as the heaters actually in use contain from 40 to 120 gallons, according to size, there is an ample supply of hot water through the hours of daylight. Solar water heaters of this kind have been installed on the roofs of many houses in Southern districts. They work admirably, and even in less favourable places have been found useful.

Given a mild climate where there is no need of elaborate heating devices for keeping comfortable, and all ordinary domestic needs are easily satisfied if the region is one where sunshine is available, and the demands of power-using industries can be readily met where hydraulic power is available, irrespective of solar power; or, in the sunshine belt, by solar power auxilary to water-power, or even alone. No matter how completely the stored fuel supply is exhausted, the earth from the equator 30° north and south can, by means even now at hand, be thoroughly habitable under the general conditions of our existing civilisation. To latitude 40° the conditions are somewhat less favourable, but the *status quo* can be generally preserved by skillful combination of existing sources of power. In higher latitudes there is trouble ahead, and while in some quarters of the earth the climate comes to the rescue, in others herculean engineering efforts will be needed to provide power for warmth, light, and industry.

The exhaustion of coal, or its extreme scarcity, will, therefore, bear hard on the north temperate zones, in which at present much of the world's industry is centered. Only resort to the most desperate efforts can render these available for the support of a large population beyond latitude 45°. As soon as the hardness of the struggle and the competition of more favoured climates has forced a migration sufficient to diminish greatly the density of population, the natural fuel supply will tend to increase and check further migration.

We are steadily exhausting the stored fuel supply that makes the world's present centres of population and industry tenable. Tides, wind, and sun may be called to the rescue; but these remedies are a desperate resort in a really unfriendly climate, and will hardly suffice to check the migration to regions of less strenuous needs. This shifting of population and industry will be none the less inevitable because it chances to be slow. Every fresh remedy for lack of fuel will make the process more easy and gradual; but when the fuel is used up, the sheer force of competition will ensure the dominance of the regions which make small demands for uneconomic uses of power.

THE AUXILIARY MACHINERY OF STEAM VESSELS

II—FEED-WATER FILTERS, STEERING GEAR, AND EVAPORATING, DISTILLING, AND REFRIGERATING MACHINERY

Part I of this article, which appeared in the July Number, treated of Turning and Reversing Engines, Air and Circulating Pumps, Condensers, Feed Pumps, and Feed Heaters.

By Jasper E. Cooper

There is little need to emphasise the necessity of fitting a thoroughly efficient filter to remove matter in suspension in the feed-water before it enters the boilers after leaving the condenser. There is little excuse for a boiler giving trouble with deposit of lime, because, although the filter will not extract lime, or salt in solution, from the feed-water, the heater does this to a great degree, and if the evaporator is used to make up the lost water, lime cannot enter the boiler to any large extent. There are, however, other substances to be dealt with, more dangerous in a boiler than a deposit of lime.

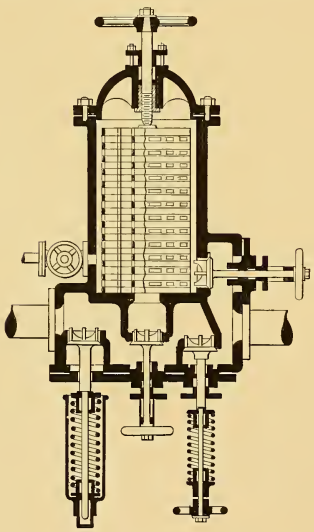


FIG. 25.—THE HARRIS FILTER, MADE BY THE HARRIS PATENT FEED WATER FILTER, LTD., GREENOCK AND LONDON

An analysis of a filter deposit from engines without internal lubrication has shown that about 20 per cent. of the deposit is fatty matter. This, no doubt, enters the cylinder, and so becomes associated with the steam from the piston and valve rods. When a number of auxiliary machines are exhausting into the condenser the quantity of oil trapped becomes greater. Engines of the enclosed type, in which the cranks work in a bath of oil, are by far the most troublesome in this respect.

Oil after being deposited in a boiler does not retain its original appearance. It is distilled, or burned off, leaving a deposit which, from appearances, one would say was quite harmless. It is, however, a very poor conductor of heat, and consequently, if allowed to remain, will very probably cause overheating. One would naturally think that oil, being lighter than water, would remain on the surface; but it is evident that such is not the case. The reason is that the oil, coming into contact with small particles of lime and sticking to them, soon becomes as heavy as the water, and so is circulated about with it until, coming into contact with a tube or plate, it sticks to the surface. In this way the under sides of the tubes are just as liable to become incrusted as the upper sides, and in this way, also, it differs from the

ordinary boiler incrustation. The filter should, therefore, be capable of extracting all the oil from the water before it is returned to the boiler.

Filters can be divided into two classes, —high-pressure filters, fitted between the feed pumps and the boilers, and consequently subjected to a pressure slightly in excess of the boiler pressure; and suction filters, fitted between the air pump and the feed pump. In the latter the area of filtering medium is necessarily much larger than in the former, and consequently this class of filter takes up more space than the former.

Before proceeding to describe some of the principal forms of filters it would be as well to say something about the media used in them. It would be a difficult task to mention a substance of seemingly suitable character which has not been tried, at some time, as a filtering medium. Silk, calico and many other fabrics, even cocoanut fibre matting, have been tried. Towelling has given some satisfaction in certain classes of filter. Sawdust from all kinds of wood, both in its natural state and roasted, coke, charcoal, and cork dust have all received attention, and it cannot be said that a thoroughly satisfactory substance has yet been found. A filtering medium should be cheap and easily obtainable; it should not wear out rapidly, necessitating the storage of large quantities of it on board; and it should be of such a texture as to arrest the matter in suspension in the water without offering great resistance to its passage.

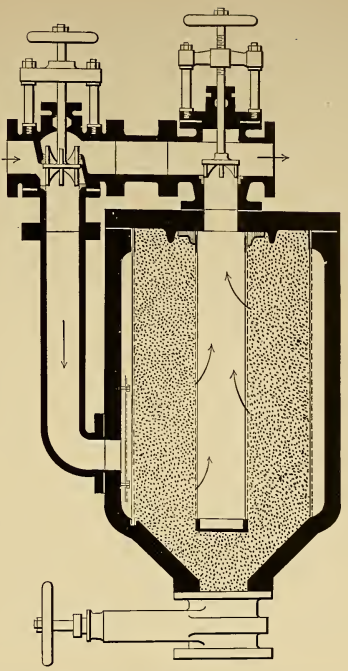


FIG. 27.—FILTER MADE BY MESSRS. MATHER & PLATT, LTD., MANCHESTER

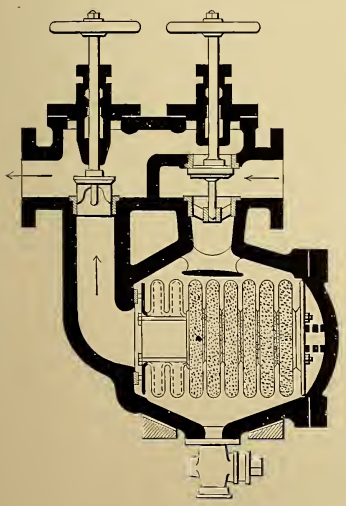
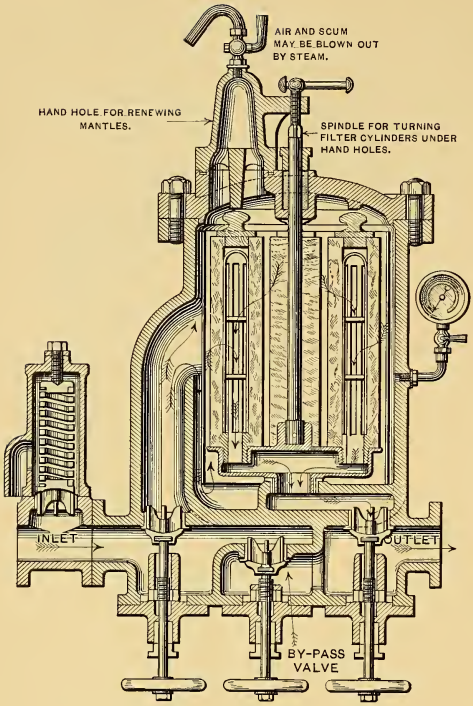
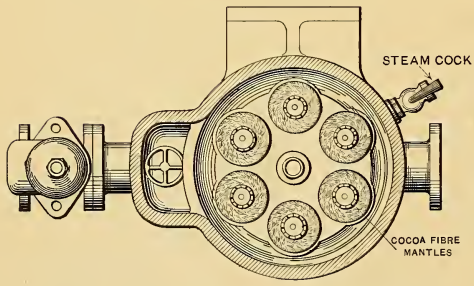


FIG. 26.—THE RAILTON & CAMPBELL FILTER, MADE BY RAILTON, CAMPBELL & CRAWFORD, LIVERPOOL

The Harris filter is made in many and varying designs to suit different requirements, and to work on the suction or delivery side of the hot well or boiler feed pump, or on the air pump discharge; but they are all constructed on the same general principles. Those intended for the air pump discharge, however, have


AIR AND SCUM MAY BE BLOWN OUT BY STEAM.
HAND HOLE FOR RENEWING MANTLES.
SPINDLE FOR TURNING FILTER CYLINDERS UNDER HAND HOLES.
INLET
OUTLET
BY-PASS VALVE

VERTICAL SECTION



PLAN SHOWING THE ARRANGEMENT OF THE FILTER MANTLES

FIG. 28.—FILTER MADE BY MESSRS. ALLEY & MACLELLAN, GLASGOW

special arrangements for preventing the air discharged with the water from passing through the filters, to which, also, the auxiliary air pump discharge can be connected; and in order to reduce the back pressure on the pumps to a minimum, the area of the medium is greatly increased.

Fig. 25 represents a Harris filter as arranged for the delivery side of a feed pump. The filtering medium is disposed in layers, between discs of wire gauze, which, in their turn, are laid in suitable recesses in brass grids, the medium, or cloths, overlapping the outer and inner edges, so that when they are compressed by the screw on the top a water-tight joint is formed between them.

A steam valve is fitted to blow from the back of the medium to assist in removing the deposit by softening the greasy matter. The filtering medium is securely held down between the discs of tinned copper gauze, fitted into the recesses in the brass grids, so that when the current of the water is reversed to clean the medium the latter is not blown out of place or torn. The internal portions of this filter are made of gun metal, or, where extreme lightness is desired, of aluminium alloy.

An automatic by-pass arrangement is fitted, by which, when the filtering medium becomes foul, the water is passed direct to the boiler. To this by-pass is attached an electric alarm, which, on the first movement of the valve, is caused to sound and warn the attendant that the filter requires sludging out. Two pressure gauges are also fitted, one communicating with the inlet and the other with the outlet side of the filtering medium, so that the resistance due to the deposit

thereon can be readily ascertained.

The Mather & Platt filter, shown in Fig. 27, consists of a closed vertical cylindrical chamber, provided internally with an open-ended, perforated steel cylinder and a perforated central gathering tube, both being covered with wire gauze and very finely perforated Muntz metal sheet, to prevent the possibility of escape of any filtering medium. A water space is provided between the inner walls of the outer chamber and the perforated internal cylinder, the gathering tube being fixed centrally and connected to the outlet valve on the top. The entire space between the two perforated tubes is tightly packed with coarsely granulated soft wood sawdust, through which the feed-water slowly percolates. The pressure gauge on the inlet side of the filter will indicate when the sawdust requires renewing by showing a pressure above the boiler pressure.

A by-pass is provided so that unfiltered water can be passed to the boilers when the filter is being cleaned. The cleaning is done by opening the sluice valve at the bottom and also two small valves at the top attached to the cover. These valves are connected with the water space of the boiler, and consequently all the sawdust is washed or blown out. The sluice and water valves are then closed and fresh medium is put in through handholes provided for that purpose.

Fig. 28 represents the Sentinel multiple filter, made by Messrs. Alley & MacLellan. The filtering mantles are carried on perforated brass tubes which are mounted on a casing free to revolve about a central shaft, or spigot. This casing can be operated by a central shaft passing through the cover. The mantles are so arranged that by turning the shaft they can be brought, in succession, under a handhole through which they can be removed and new ones put in.

The Railton & Campbell filter, shown in Fig. 26, has a deeply corrugated cylinder as a base for the filtering medium, which consists of cloths tied with strong twine at the bottom of the corrugations in slip-knot fashion. A by-pass and the usual fittings are provided.

One type of the Edmiston filter, made by the Glasgow Patents Company, Ltd., is represented in Fig. 29. Here a corrugated grating is covered with filtering medium and the feed-water passes through it. The resistance is usually about 5 pounds at the start, rising to 10 pounds or 15 pounds for normal working; when 20 pounds pressure is reached the filter should be cleaned. Steam and soda cocks are provided for this purpose. In another type of Edmiston filter the base for the medium is cylindrical without any corrugations, but two

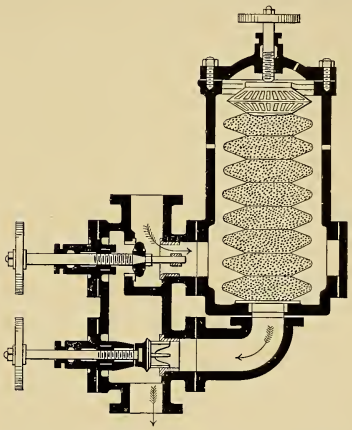


FIG. 29.—THE EDMISTON FILTER, MADE BY THE GLASGOW PATENTS CO., LTD., GLASGOW

layers are provided, so that the water is filtered twice before being led to the boiler.

Webster's combined filter and heater, Fig. 30, has been applied to ships varying from 100 to 10,000 H. P. As the name implies, this apparatus both filters and heats the water in one vessel, and consequently simplifies the arrangement of pipes and connections. As will be seen from the illustration, the feed heater, in the form of a double convoluted steam tube, is inserted from below into the cylindrical chamber, and is surrounded by a cylindrical filtering surface of a large area in the form of a filt-

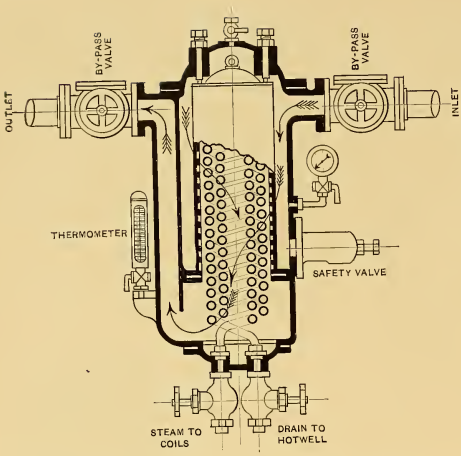


FIG. 30.—WEBSTER'S COMBINED FILTER AND HEATER, MADE BY MESSRS. A. & R. BROWN & CO., LIVERPOOL

ering tissue or fabric surrounding a perforated inner chamber. The feed-water is admitted by a side branch to the external chamber, thence through the filtering medium to the inner chamber, where it comes in contact with the heating tubes, and thence is taken to the boiler.

The inner filtering chamber and surrounding medium can be conveniently lifted and removed from the outer chamber for the purpose of cleansing and renewal, leaving the heating tubes untouched if they do not require attention. There are the usual accessories of pressure gauge and thermometer, and the very necessary by-pass between the feed inlet and outlet, so that the feed may be continued without interruption when the filter is open for cleansing.

The List & Munn filter, shown in Fig. 29, is made by Messrs. Carruthers & Co., of Glasgow, and sometimes takes their name. It is of the suction-side type, and has been fitted to engines of from 20 to 30,000 H. P. It consists of a tank with a horizontal division plate near the bottom, separating the unfiltered from the filtered water. The filtering cells are placed on this division plate. Each cell consists of a group of four or six cages, made of expanded steel and covered with the medium, which is usually of light canvas or Turkish toweling. The impure water passes through two strata of medium when there are four cages per cell, and through three strata when six cages are used. There are two tanks, so that one group of cells can be cleaned whilst the other is filtering water for the boilers.

The water to be filtered enters the tank through the valve shown at the left and passes through the cells, as indicated by the arrows in the sectional view, to the lower part of the tank, whence it is taken through an outlet valve to the feed tank or pump. The chief features of this filter are that it acts by gravity alone and that the area of filtering surface in the outer stratum is only about 1000 times that of the feed pipe.

The steering gear of a steamship is probably the most important of all the auxiliaries. The safety of the ship is directly dependent upon it; many are

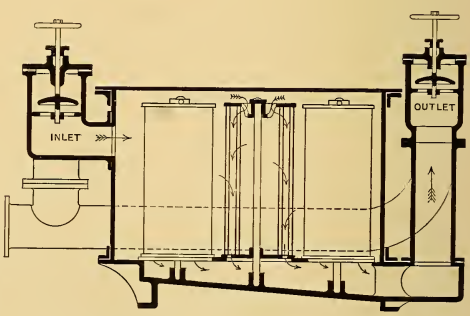


FIG. 31.—FILTER MADE BY MESSRS. J. H. CARRUTHERS & CO., GLASGOW

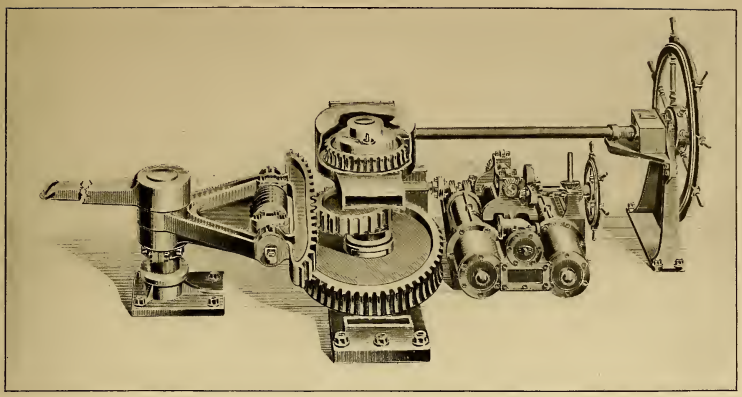


FIG. 32.—COMBINED STEAM AND HAND STEERING GEAR, MADE BY MESSRS. HARFIELD & CO., LTD., LONDON. PART OF THE PEDESTAL IS SHOWN CUT AWAY SO THAT THE ECCENTRIC OPERATING PINION CAN BE SEEN, AND ALSO THE CONNECTION BETWEEN THE STEAM AND HAND-POWER GEAR

the accidents and many the delays caused by a hitch with the steering apparatus. A hand gear is always fitted as a stand-by, and should be capable of steering the ship whether the usual motive power is steam, electricity, or hydraulic power. Steam power is the most common, and when it is so arranged that the engine is in the engine room, under the immediate supervision of the engineers, there is really very little to complain of. Electric power is sometimes used, and gives good results; the first cost, however, of an electric apparatus is probably greater than that of a steam-driven one.

The apparatus shown in Fig. 32 represents one form of steering gear made by Messrs. Harfield & Co., Ltd., of London. The chief feature of this gear is the arrangement whereby the power required to move the rudder in any position remains nearly constant. It is evident that as the rudder is deflected more and more from its central position the pressure on it, due to the resistance of the water, becomes greater, and unless there is some special arrangement, as in this case, the power required to move the rudder would also become greater as the deflection increased. We should, therefore, require an engine capable of dealing with the resistance when at its maximum. But in the Harfield gear the mechanical advantage is increased as the rudder is deflected, and the engine is, consequently, always exerting a constant power. These results are obtained by means of the eccentric pinion and corresponding quadrant, shown in the illustration.

It will readily be seen that with the rudder in its central position the eccentric pinion will give a rapid motion to the quadrant, and that this will be reduced as the helm is put over in either direction. When using the steam gear, the hand-wheel merely actuates the steam valve, and the turning of the engines that follows tends to close the valve again, so that there is a direct relation between the motion of the hand-wheel and the distance through which the rudder is moved. To disconnect the steam gear, the clutch, shown beneath the pinion, is raised. The hand gear can then be used, and the compensating arrangement is then found extremely useful, one man being able to do the work for which three would be necessary with the ordinary gear. A spring buffer is provided, as shown, to

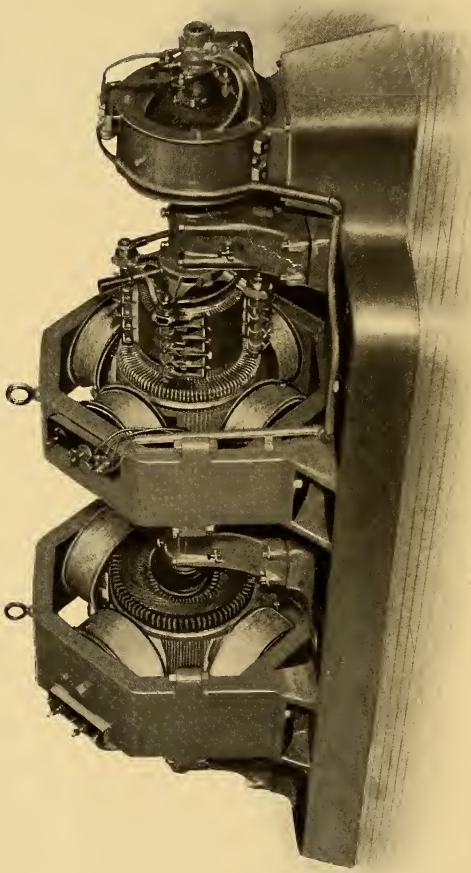


FIG. 35.—A MOTOR-DRIVEN GENERATOR AND EXCITER MOUNTED ON A SINGLE BEDPLATE, FOR ELECTRIC STEERING GEAR SERVICE. SUPPLIED BY THE ELECTRO-DYNAMIC CO., PHILADELPHIA., U. S. A.

lessen the shock that would otherwise be caused on the gear by a heavy wave striking the rudder. This gear is sometimes arranged with the engine in the engine room, chains being led to a drum on the pinion spindle.

The principle of the electric steering gear as made by the Electro Dynamic Company, of Philadelphia, Pa., is as follows:—If we prepare two equal resistances and connect them in parallel to a source of electrical current, the current will flow equally in both (Fig. 33). Suppose, now, we provide two swinging contact arms, one to make contact at different points on each resistance, and connect these two arms by a wire, with an ammeter M in the circuit; we shall then find that as long as the two arms make contact at corresponding points on the resistances no current will flow in the connecting or "balancing" wire.

If, however, we move the contact arm of B to a new position, a current will immediately commence to flow in the balancing wire, and will continue to flow until the arm S is moved to a new position corresponding exactly with the new position of B. The direction of the current in the balancing wire will depend upon which way the contact arm B is moved, and the volume of current will depend upon how far the arm is moved around the circuit. We have here the principle of the Wheatstone bridge, and the peculiar adaptability of this principle to a steering gear will be quickly appreciated.

If, instead of an ammeter, we place in the circuit of the balancing wire an electric motor capable of running either way,

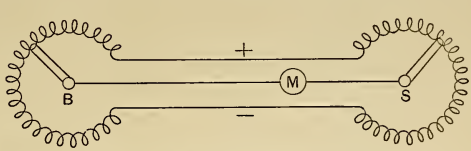


FIG. 33.—DIAGRAM ILLUSTRATING THE PRINCIPLE OF THE ELECTRO-DYNAMIC COMPANY'S ELECTRIC STEERING GEAR

and connect the motor by mechanical means to rotate the contact arm S, current flowing through the balancing wire will operate the motor until the position of the arm S corresponds to the position of the arm B, when no current will flow and the motor will stop. Any change in B will be followed by a similar change in S.

If this principle could be applied to a steering gear without the introduction of other elements, the problem would be a very simple one. For a number of reasons, however, this is not practicable, the principal reason being that the currents continually flowing in the resistances would be excessive. Modifications have, therefore, had to be introduced, although the principle remains the same. In the wheel-house is placed the steering column, and within the column is one of the resistances represented in the diagram, also the contact plate, and the sweep making contact on it. The wheel is geared to the sweep, so that to throw the rudder from hardover to hardover the wheel must be revolved ten times. Close to the helm is a frame supporting another resistance with its contact plate, as shown in Fig. 34. The sweep of this rudder column is connected to the helm so as to move as the rudder moves. The resistances of both the rudder and steering column are supplied with current from the dynamos of the

FIG. 34.—RUDDER COLUMN RESISTANCE FRAME

ship, or from an independent source. The sweep of the steering column is connected electrically with the sweep of the rudder column by a small wire.

In the dynamo room is placed a motor-driven generator, Fig. 35, with an exciter attached to the same shaft. The fields of the exciter are in circuit with the balancing wire, connecting the steering resistance with the rudder resistance. The motor driving the generator and exciter receives current from the dynamos of the ship. By suitable proportions of generator and exciter the effect of the small current in the balancing wire is multiplied sufficiently to drive the rudder motor, which is located in the stern of the ship, and geared to the helm so as to turn it in either direction as required.

In some cases it is desirable to have the steering gear entirely independent of the other electrical apparatus of the ship. For such a case the exciter illustrated in Fig. 35 is coupled to the engine-driven generator, Fig. 36, and all the power necessary for steering the ship is taken from one engine. When such an equipment is used, suitable provision is made for uncoupling the exciter and steering the ship with power from one of the lighting generators in case of an emergency.

Let us now consider how the apparatus operates. If the man at the wheel desires to change his course, he manipulates his wheel exactly as he would if it were connected directly with the rudder. The movement of the wheel varies the position of the sweep of the resistance in the steering column; this starts a small current flowing through the balancing wire and the fields of the exciter. This current is multiplied in the manner indicated above, and power is transmitted to the rudder motor, thus causing the motor to turn the rudder. The rudder will continue to move until the sweep of the rudder column is moved to a position corresponding with the position of the sweep of the steering column, when current will cease to flow in the balancing wire, and the generator and rudder motor will cease to operate. The rudder will, therefore, assume a position corresponding with the sweep of the steering column. During this time the motor driving the generator and exciter has had to do work proportional to the power required of the generator, and also a slight amount of work necessary to rotate the two armatures. When

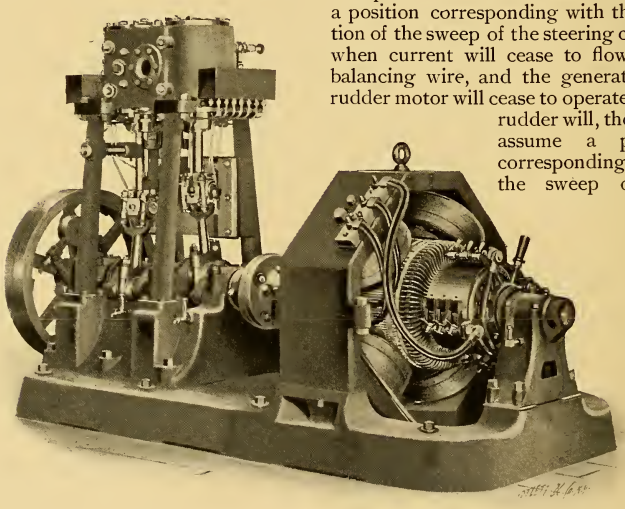


FIG. 36.—AN ENGINE-DRIVEN ELECTRIC GENERATOR FOR SHIPBOARD USE

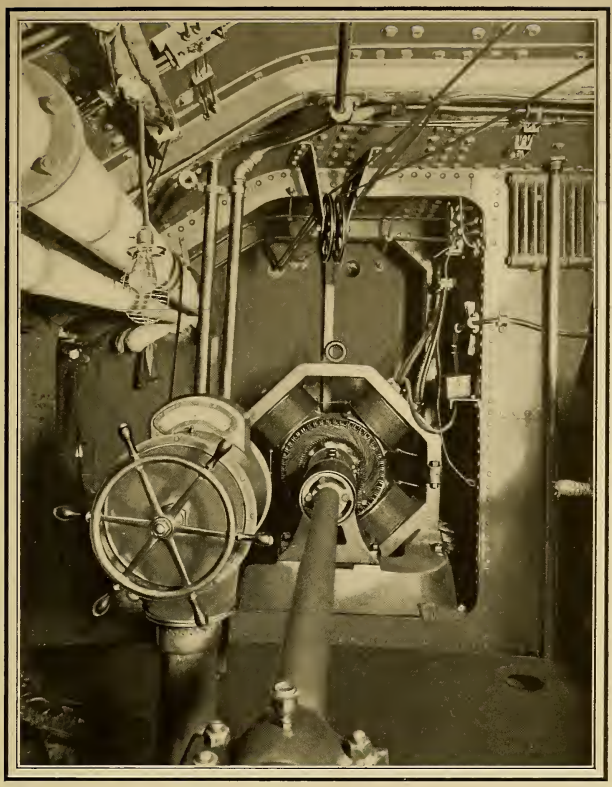


FIG. 37.—RUDDER MOTOR AND AUXILIARY STEERING COLUMN OF THE RUSSIAN CRUISER "VARIAG"

current ceases to flow through the balancing wire, no power is required, except the friction load of driving the generator and exciter armatures in dead fields. This power is very small. The method of multiplying the effect of the current in the balancing wire makes it possible to use very small currents in the resistances, these currents being about two ampères each, not enough to operate four incandescent lamps.

That the man at the wheel may always know how the rudder is responding to his wheel a rudder indicator is mounted on or near the steering column. This apparatus has been fitted to a number of American and Russian warships, as well as to several merchant vessels. Fig. 37 shows the rudder motor and auxiliary steering column of the Russian cruiser *Variag*.

That an adequate supply of pure fresh water is essential to the health and life of man will be acknowledged by all. That pure water is necessary to make up the feed for the modern water-tube boiler will be admitted by most engineers. Hence, the necessity of the

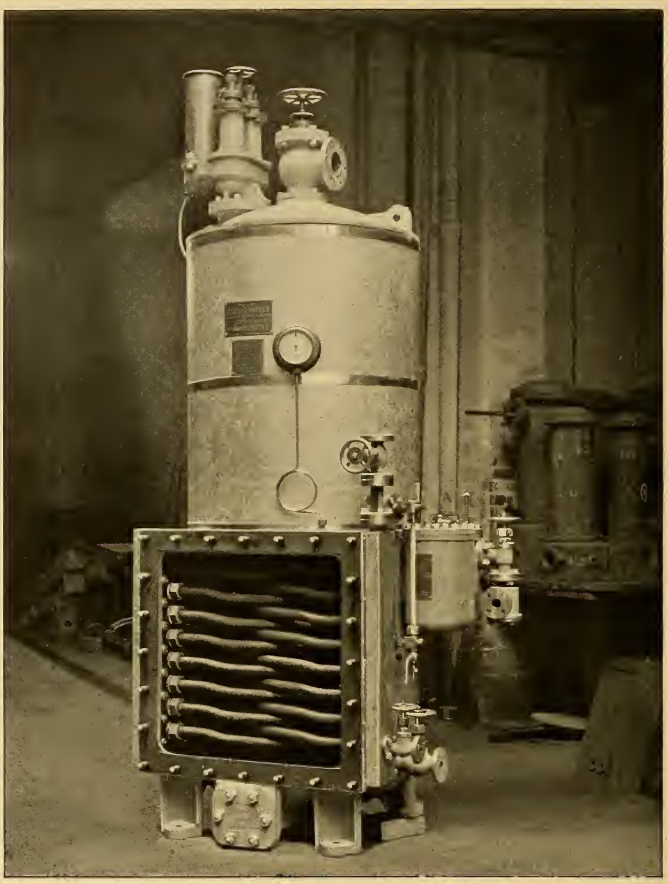


FIG. 38.—AN EVAPORATOR MADE BY MESSRS. CAIRD & RAYNER, LONDON. EACH COIL CAN BE REMOVED SEPARATELY BY UNSCREWING NUTS WHICH MAKE METALLIC JOINTS AT EACH END OF THE COIL. NO PUTTY OR OTHER JOINTING MATERIAL IS USED

evaporator on board all steam vessels, from the very largest to the small fish trawler. To carry a supply of fresh water sufficient for these purposes is impossible; it is, therefore, obtained by evaporation from sea water.

The general principle of the mode of procedure is as follows:—The salt, or impure, water is boiled and converted into steam; this is then led to another vessel where it is condensed and changed back to water; but the impurities having been left behind in the boiler, or evaporator, the resulting water is pure and fit for drinking or culinary purposes. This operation, though apparently very simple, requires specially designed apparatus for its perfect and economical

accomplishment, and since all fresh water distilling apparatus are much the same, relying upon the same principle, the writer will describe merely one form, that made by Messrs. Caird & Rayner, Fig. 38, being a good example.

Let us first consider the boiler, where, in the simplest form of distiller, the impure salt water is converted into vapour. Remembering that the vapour, or steam produced from the impure water, is to be condensed into pure water, it is essential that the steam be so far dry as not to carry over with it any of the impure water. Ample steam space must be provided so that no "priming," or carrying over with the vapour of the smallest quantity of salt or other impurities in the water to the condenser, can occur; otherwise the distilled water will be tainted.

Again, since all the impurities in the original or primary water are retained in the boiler, it follows that these impurities accumulate more and more, and ultimately form a mineral deposit which is extremely difficult to remove and a very poor conductor of heat. Should the heating surfaces be allowed to become coated with such a non-conducting scale their efficiency becomes greatly impaired. The presence of such a scale

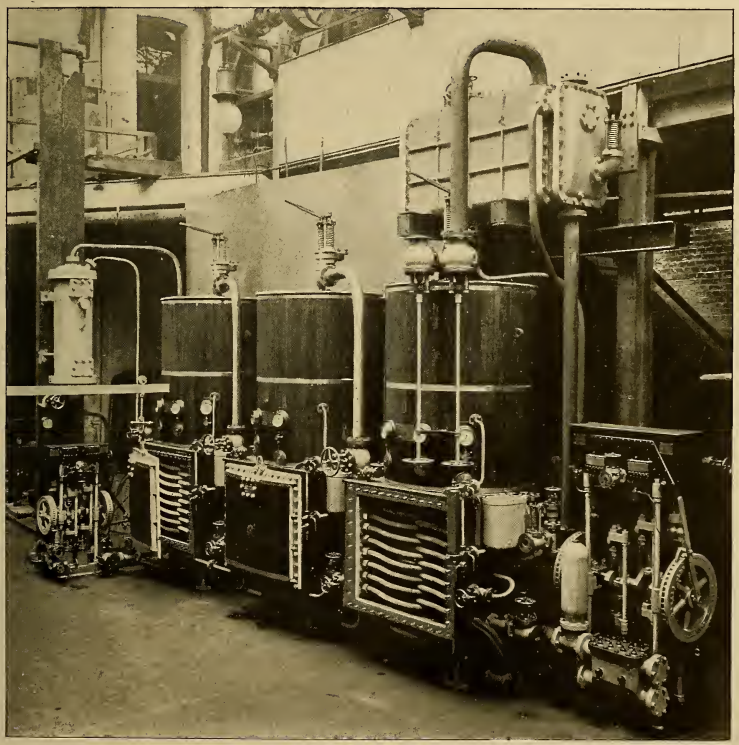


FIG. 39.—A TRIPLE-EFFECT DISTILLING PLANT AS FITTED IN VESSELS OF THE BRITISH NAVY BY MESSRS. CAIRD & RAYNER, LONDON.

also, leads to overheating and bulging of the plates of the boiler, with a possible rupture as the result.

From the above it will be clear that a boiler used for distilling fresh water from sea water (where only a boiler and condenser are used, as in the simplest plant) must be periodically stopped and thoroughly cleaned from all scale. This, in most types of boilers, is rather a difficult and expensive operation and takes up time. Such a boiler must be specially designed so that every part of the interior surface, and most specially those parts subjected to the most intense heat from the fuel, are easily accessible for cleaning. The condenser may be simply a coil, or coils, of tube, suitably connected at one end to the steam supply pipe from the boiler, and at the other to the pipe by which the distilled water is led to the storage tanks, the coil, or coils, being immersed in a tank, or well, of cold water, which, when it becomes heated, must be changed. The tubes or coils are usually enclosed in an outer casing through which the stream of cold water is passed, either by gravity or by a pump. Such is the simplest form of fresh water condensing plant, but it is not used in marine practice in this form. Certain modifications are introduced, which make it more economical. The efficiency of the apparatus just described is only one pound of water gained to one pound evaporated.

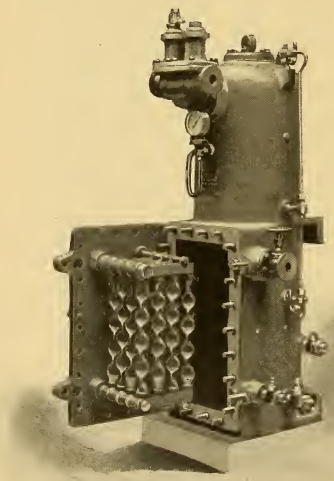


FIG 40.—AN EVAPORATOR MADE BY MESSRS. ROYLES, LTD., IRLAM. THE TYPICAL CHARACTER OF THE ROW TUBE IS HERE WELL SHOWN

One of the modifications spoken of is the introduction of another vessel called an evaporator. The evaporator of Messrs. Caird & Rayner is a vertical, cylindrical iron vessel having a rectangular opening in the lower part, closed by a door. Within this vessel is a series of coils practically forming one long length of tube, through which steam can be passed from end to end.

The object of the evaporator is to produce steam from salt water or impure water by the heat from steam from a boiler, the boiler steam being led to the tubes which are kept surrounded by the water to be evaporated. To maintain a constant level of this water a specially designed automatic regulating valve is fitted to the evaporator, as well as a glass water gauge and safety valve. By this arrangement we get for each pound of water evaporated by the boiler 1 pound of fresh water, as before, and, in addition, the quantity produced by the evaporator, which is about 0.8 pound or 0.9 pound. But we still have the boiler using salt water as feed. In marine practice this is not considered advisable. Steam is, therefore, taken from the main boilers, or from the exhaust of the auxiliaries, and passed through the coils in the evaporator. The vapour from the salt water is carried to a separate condenser, or to the main, or auxiliary condenser, as may be desired.

With such plants pumps are generally required for circulating the cooling water through the condenser, for pumping the distilled water to the storage tanks, and for pumping away a certain quantity of the brine or salt water from the evaporator to prevent the density from getting too great, and in most cases for also

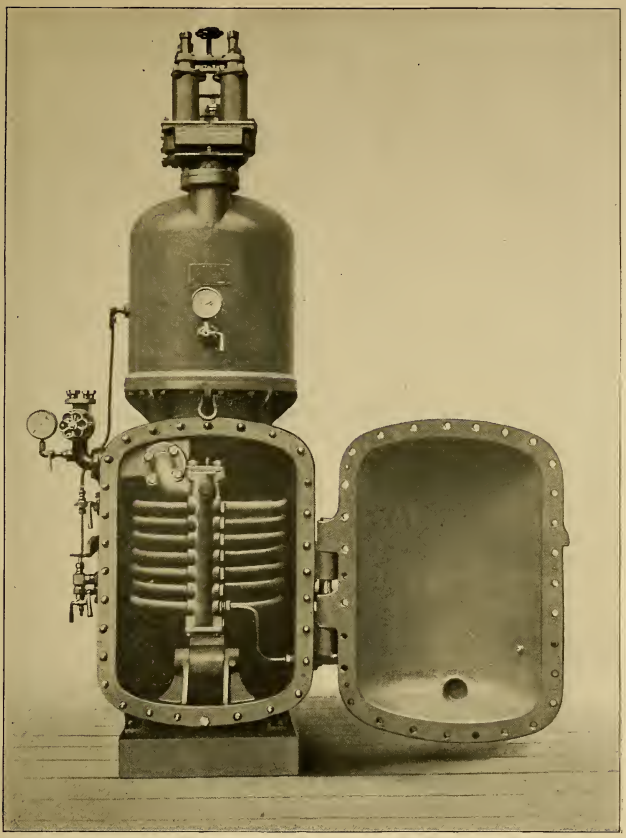


FIG. 41.—AN EVAPORATOR MADE BY MESSRS. G. & J. WEIR, LTD., CATHCART, GLASGOW. THE DOOR IS SHOWN OPEN FOR CLEANING

feeding the evaporator. One triple pump is made to do these duties in the marine type distiller. Fig. 39 shows a complete set of apparatus as constructed for several torpedo-boat destroyers.

Every large passenger-carrying steam vessel is now fitted with refrigerating apparatus, and this machinery, as well as all the other auxiliaries, is, of course, under the care of the engineers. Some vessels, those used for carrying meat or fruit, have the greater part of their holds kept at a temperature below freezing point, and it is, of course, obvious that in such a case the refrigerating machinery is of the utmost importance, as the quality of the whole cargo depends directly upon it.

It may be well here to briefly consider the principles involved in mechanical refrigeration. If two bodies of different temperatures are in close proximity to each other, heat will flow from the hotter to the colder one until their

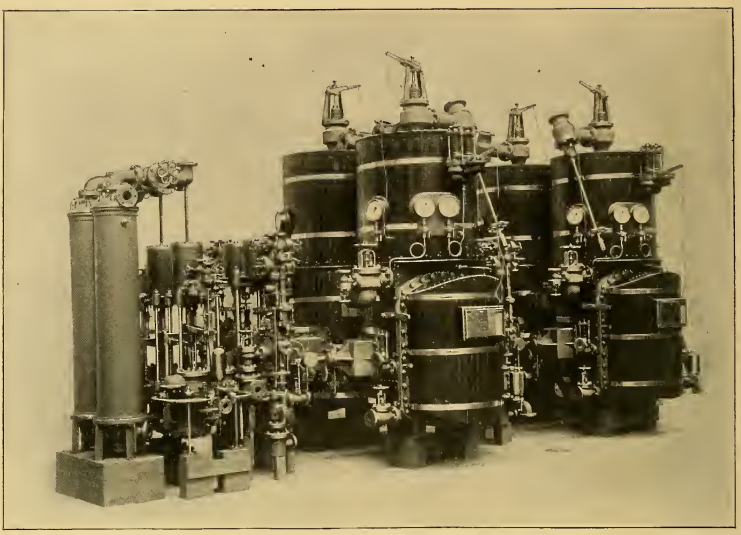


FIG. 42.—EVAPORATING AND DISTILLING PLANT, ADMIRALTY TYPE, INSTALLED BY MESSRS. G. & J. WEIR, LTD.

temperatures are the same. Consequently, the duty of the refrigerator is not only to reduce the temperature of any given object, but to maintain it at that temperature. The first law of thermodynamics tells us that heat and mechanical energy are mutually convertible; the second, that heat cannot pass from a body at a low temperature to a body at a higher temperature without external aid. On these laws all refrigerating machines are dependent. The cycle of a perfect refrigerating machine is exactly the reverse of the cycle of a perfect heat engine. In the latter, heat is taken into the engine at a high temperature, is made to do work, and is passed out at a low temperature. In the former, heat is taken into the machine at a low temperature, work is done on it, and it is given out at a high temperature. One great difference, however, between the two operations is that, whereas the efficiency of the heat engine is higher the greater the difference between the two temperatures, the efficiency of the refrigerator is greater the less the difference between the original and final temperatures.

Refrigerating machines can be divided into two classes:—First, machines using air as a medium; second, machines depending upon the alternate liquefaction and evaporation of some volatile liquid. There are two kinds of air machines,—the open cycle and the closed cycle. In the former the air is not confined in pipes, as it is in the latter. The cycle of operations is as follows:—Air is compressed in a cylinder up to about 60 pounds. It is then cooled in a coil surrounded by cold water, and is then allowed to expand. The result of this expansion is that the temperature falls much below freezing point. The objection to the air machine is that the moisture in the air is frozen and causes trouble with the valves. The efficiency, too, of the air machine is not very high, owing to the great difference between the final and original temperatures.

In the second class, the medium is some volatile liquid. No substance can change from solid to a liquid form or

from a liquid to a gaseous form without absorbing a definite quantity of heat, and in the reversal of this process the same amount of latent heat must be given up. This latent heat varies in amount for various substances, but the points to be considered in determining the liquid to be used are mainly the following:—Its latent heat of vapourisation must be as great as possible; it must be cheap and readily obtainable; it must be safe in practical working; it must not deteriorate with the constant compression and expansion; and it must work within reasonable pressure limits.

The compression refrigerating machine is the most important and by far the most common form used to-day. The method of operation is as follows:—The gas is compressed in a cylinder and then taken to a condenser, where it is cooled by a circulation of cold water; this cooling action, together with the compression, causes the gas to liquefy and collect at the bottom of the condenser. It is then passed through an expansion valve, which is capable of being regulated to a nicety, into the refrigerating coils, where the pressure is kept low by the suction of the compressor. The liquid vapourises in these coils, and in doing so absorbs the required amount of latent heat. This heat is taken mainly from the medium itself, which becomes very cold, and this cold vapour circulating through the refrigerating coils collects heat from the surrounding objects.

Various media have been tried, but the only ones that have come into com-

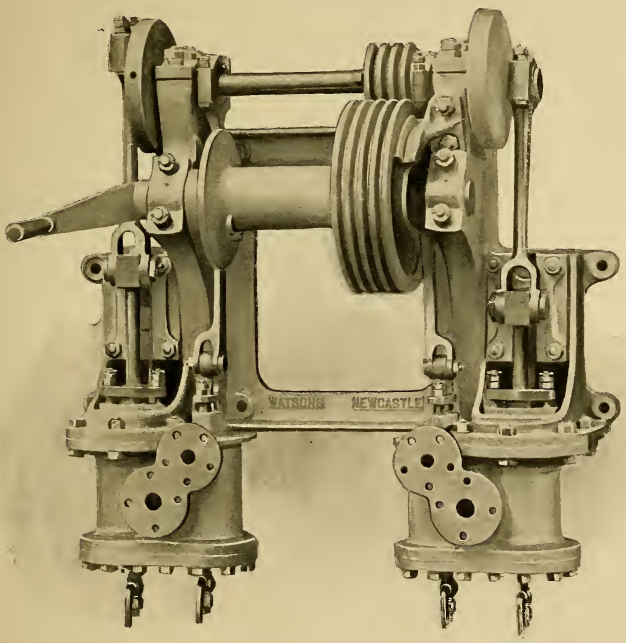


FIG. 43.—ASH-HOISTING ENGINES MADE BY MESSRS. HENRY WATSON & SONS, NEWCASTLE-ON-TYNE

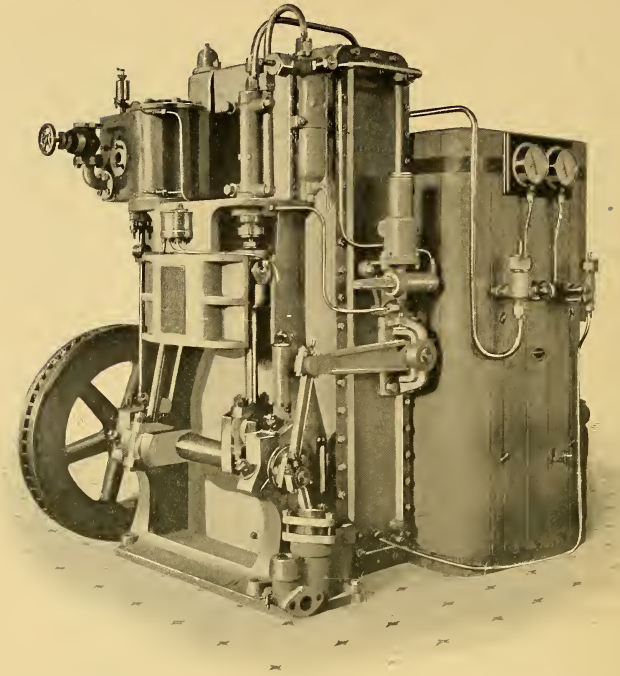


FIG. 44.—A CARBONIC REFRIGERATING MACHINE, MADE BY MESSRS. J. & E. HALL, LTD., LONDON

mercial use to any extent are carbonic acid, sulphuric ether, sulphur dioxide, and anhydrous ammonia. The ether machine was the first to be used, but it is now obsolete, owing to the fact that the compressor has to be very much larger than with the other liquids. Ammonia gives good results in practice, and is very frequently used; but owing to its poisonous properties great care has to be exercised to avoid any leaks. With ammonia compression machines there are two systems of working, about the respective merits of which much controversy has taken place. They are the "wet compression" and the "dry compression" systems. The former consists in the regulating valve being so adjusted that the vapour returns to the compressor in a super-saturated state. Dry compression consists in regulating the expansion valve so that only as much liquid is admitted to the refrigerating pipes as will entirely vapourise there. Under this condition the gas returns to the compressor in a perfectly dry state, and is superheated there.

The most generally used medium on board ship, however, is probably carbonic acid, or, more correctly, carbonic anhydride (CO_2), which is the most powerful refrigerant applicable to commercial purposes. Of the carbonic acid machines on the market, that made by Messrs. J. & E. Hall, Ltd., is probably the best known, and since it has been adopted by the British Admiralty and many of the large steamship companies it represents a good example of modern practice.

The apparatus consists of three parts:

—1. The compressor, into which the gas is drawn from the evaporator and is compressed; 2. The condenser, consisting of coils in which the compressed gas is cooled and liquefied; and 3. The evaporator, consisting of coils in which the liquid carbonic anhydride evaporates, producing any degree of temperature that may be required down to 80 degrees F. below freezing point.

The compressors for large machines are bored out of solid steel forgings, partly to secure strength and partly to ensure soundness of material, and to provide a perfect bore in which the cup leathers of the pistons may work. Compressors for the smaller machines are cast in a special bronze. An important feature is the arrangement of valves, the suction and delivery being identical for facilities of interchange. The glands are made gas-tight by means of two cupped leathers on the compressor rod. A special oil is forced into the space between these leathers at a greater pressure than the maximum pressure in the cylinder, so that whatever leakage takes place at the gland is a leakage of oil, either into the compressor or into the atmosphere, and not a leakage of gas. Any of the oil which passes into the compressor, beyond that required to fill the clearance volume, is discharged with the gas through the delivery valves. In order to prevent this passing into the condenser, all the gas is delivered into a separator from which the oil is drawn from time to time.

The condenser consists of coils of copper or wrought iron hydraulic pipe of about 13-16-inch bore. These are either placed in a tank and surrounded with water or water is allowed to trickle over them. The coils are welded together into such length that joints inside the tank are unnecessary. The evaporator also consists of nests of pipe, welded up into long lengths, inside which the liquid carbonic anhydride evaporates. The heat required for evaporation is taken from the brine surrounding the tubes, when brine is used as a cooling medium, or from the air direct.

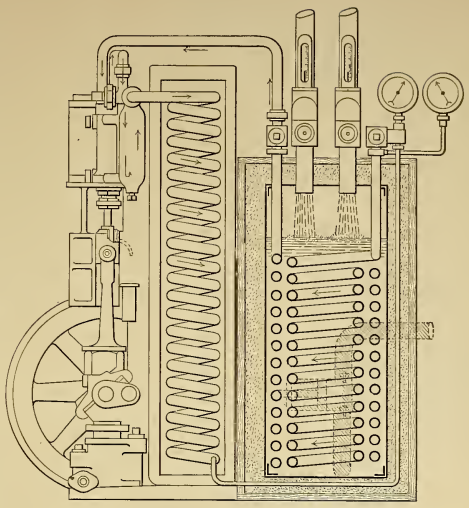


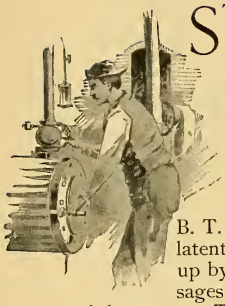
FIG. 45.—VERTICAL SECTION OF A HALL REFRIGERATING MACHINE

Fig. 45 represents a section through Hall's vertical type marine carbonic refrigerating machine. It shows very clearly the parts just described. Fig. 44 is an external view of the same machine. The steam cylinder is at the left of the illustration, and this works the compressor through the medium of the crankshaft. The complete charge of carbonic anhydride in these machines is so small that it might be allowed to escape into the engine room without causing any inconvenience to the engineers.

FEED-WATER HEATERS

EXAMPLES FROM CURRENT AMERICAN PRACTICE

By William Wallace Christie



STEAM while expanding in an engine cylinder or cylinders from 125 pounds pressure by gauge, containing 1189 B. T. U., to atmospheric pressure, or slightly above, containing 1146 B. T. U., has lost but 43 B. T. U. and so much of the latent heat as has been taken up by the cylinders and passages while condensing part of the steam. This total amount is only a small part of the heat put into the original cold water to convert it into steam. Where all of the exhaust passes from the engine cylinder immediately to the atmosphere, as is frequently the case, there is then a great loss of heat. One of the methods employed to recover a large proportion of this heat going to waste is the use of a feed-water heater in connection with the boiler plant.

Another source of heat waste in power plants is the loss of the heat in the flue gases, which is variable in amount, depending upon many conditions, mechanical and physical, and the ability of the stoker in charge.

As an example, say, 12 per cent. of the heat from the fuel passes up the chimney unused; 5 of these 12 are the result of high temperature, that is, temperature in excess of that required for good draught. This excess heat also may be recovered by the use of a feed-water heater called a fuel economiser.

The writer would classify feed-water heaters thus:—

Closed heaters (indirect)	{ Steam tube { Water tube
Open heaters (direct)	{ Atmospheric { Vacuum
Flue gas heaters	Economisers

Closed heaters are those in which the steam to be utilised is separated from the water by a metal wall, usually copper or brass, as pipes, which material is the most desirable. This type of heater is used where the water is least contaminated, and is considered a good boiler feed-water. Their efficiency is a direct function of the ability of the metal walls to transmit the heat from the steam to the water and the amount of circulation or breaking up the water receives in

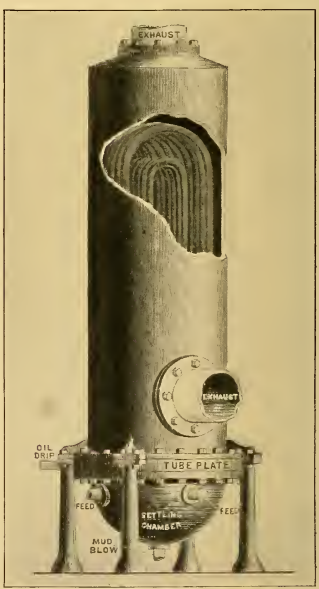


FIG. 1.—THE PATTERSON-BERRYMAN HEATER. MADE BY MESSRS. FRANK L. PATTERSON & CO., NEW YORK

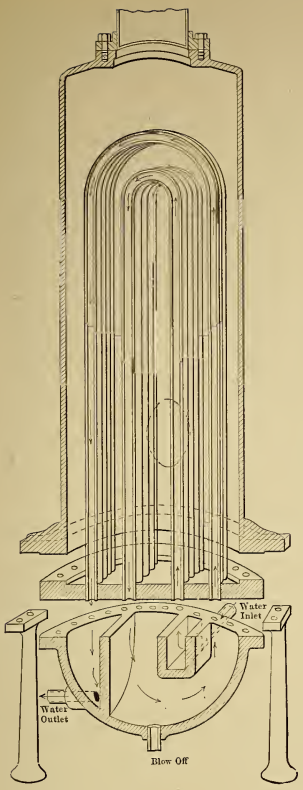


FIG. 2.—SECTIONAL VIEW OF THE PATTERSON-BERRYMAN HEATER

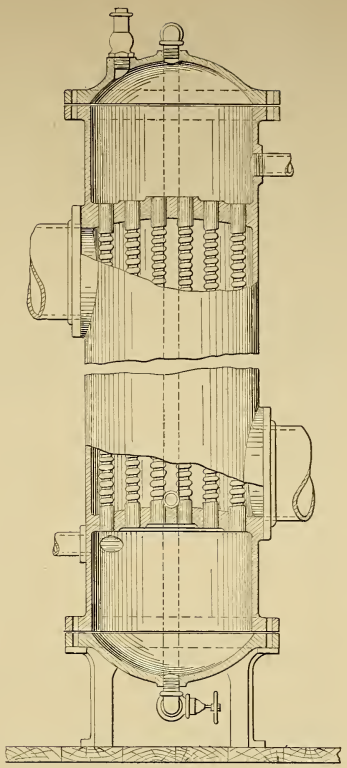


FIG. 3.—THE WAINWRIGHT HEATER. MADE BY THE TAUNTON LOCOMOTIVE MFG. CO., TAUNTON, MASS.

passing through the heater. In cases where the steam used is exhaust from the engine, and at atmospheric pressure, the highest temperature it is possible to give the feed-water is 210° or 212° F.

Sheet iron or steel shells are used for the steam-tube heaters, with water going through the shell under boiler pressure; cast iron is used for the water-tube heaters, as it is less liable to galvanic action and pitting from greasy matter and action of water and steam in the shell. The water-tube type of the closed heater is one which gives the same heating capacity in less space than is possible in the steam-tube type.

In the above types of heater the steam condensing in them is a total waste as boiler feed or where clean hot water can be utilised, unless it is passed through a filter which will thoroughly remove the oil and other impurities.

Open heaters are those into which the steam is exhausted in direct contact with and intermingled with the water. They are especially useful where the water is full of lime and other scale-forming impurities; they are fully equipped with

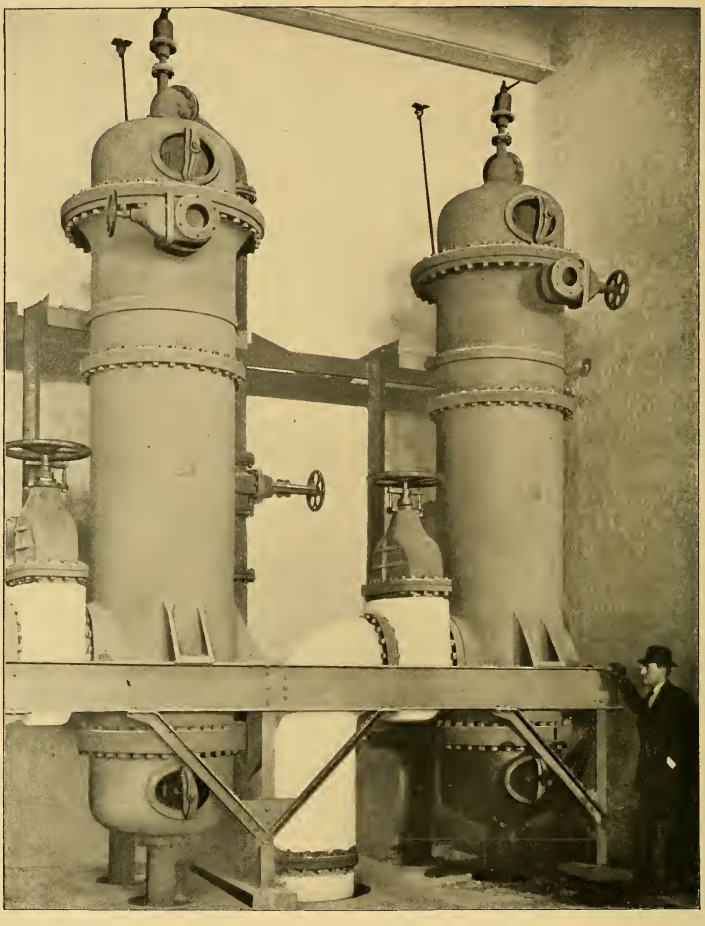


FIG. 4.—TWO 2500 H. P. FEED-WATER HEATERS IN ONE OF THE STATIONS OF THE METROPOLITAN STREET RAILWAY COMPANY, NEW YORK. MADE BY THE GOUBERT MFG. CO., NEW YORK

devices for precipitating the salts and separating and filtering out the oil, delivering a pure boiler feed-water. This type of heater may be so controlled in its action as to have the water take up all the heat in all the steam, and may raise the temperature of the water to slightly beyond 212° F.

When used with a condenser, the heater will increase the vacuum 1 to 2 inches; when used with cold feed-water, the economy increases from 7 to 14 per cent; and with feed from hot-well, 7 to 8 per cent.

Two things are very essential to the successful working of all heaters,—they must be kept clean, and sufficient exhaust steam be sent to

them to furnish the necessary heat. Of the many heaters on the market a few representative designs are shown in the accompanying illustrations. The Patterson-Berryman water-tube heater, Figs. 1 and 2, is of the pressure type, and consists of a cast iron shell and settling chamber, with ∩-shaped brass tubes expanded in a heavy cast iron tube head. In this type of heater the water passes in and through one nest of tubes, and outside of the nests of tubes, and usually is taken out at the top.

The Goubert heater, Figs. 4 and 5, is another of the pressure type which has had a large field of usefulness. The water, in entering, passes through a sleeve against a saucer-like deflector, then down into a mud drum, and finally up through the tubes, each tube end being expanded into curved heads. The upper water chamber is an invert

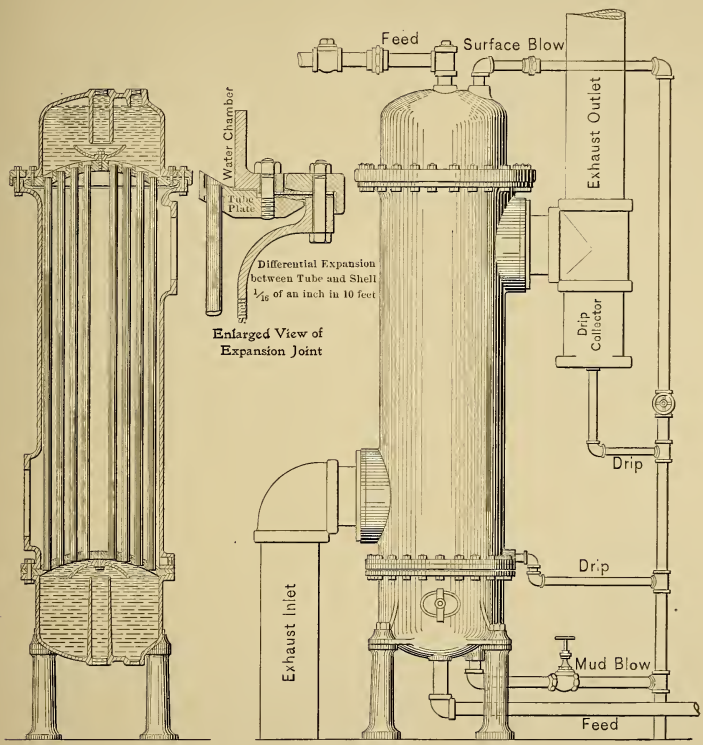


FIG. 5.—SECTION AND ELEVATION OF A GOUBERT HEATER WITH CONNECTIONS

then owing to partitions in the settling chamber, clearly seen in the sketch, the water passes through another nest of tubes and finally out for service. The steam is exhausted into the shell and of the lower one. A feature of this heater is a flexible joint between outer shell and inner tubes and their bonnet at the top.

This joint is made up of a loose flange,

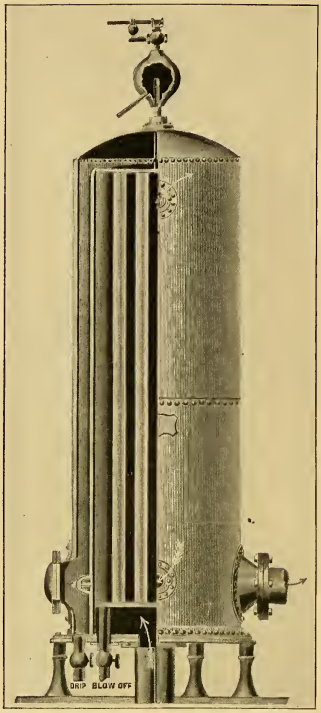


FIG. 6.—STEAM JACKET HEATER MADE BY MESSRS. WM. BARAGWANATH & SON, CHICAGO, ILL.

three gaskets, one of soft annealed copper and two of special packing with wire cloth imbedded in them, and the flange which is a part of the cast iron body of the heater. In the largest heaters of this type the makers have for some years been using partitions in the top and bottom bonnets to give a greater length of travel to the water and positive circulation. This latter method is always used in their horizontal heaters.

The Wainwright heater, Fig. 3, is of the closed type, and is made with steam tubes or water tubes, and either horizontal or vertical; this same remark will apply to practically all closed heaters. The peculiarity of this heater is in its tubes, which are of brass and corrugated, and also in the use of a long shell or body of comparatively small diameter, rather than a short shell of large diameter. The water compartments are so designed as to give an even flow at a rapid rate of travel, which aids materially a high rate of convection of heat through the pipes to the water. Tests made of heaters having different types of tubes tend to show that if water is broken up and travels at a rapid rate of speed it will take the greatest number of heat units from the steam per unit of time. The cold core in water passing through a straight tube having parallel sides is found by experiment to give way to a more evenly heated body of water in the corrugated tube, as the water, coming against the corrugations, is more thoroughly mixed than in straight tubes of a single diameter.

In the Davis-Berryman heater the body is made of "shell steel" and the head of "flange steel." The tubes are seamless drawn brass, tested to 500 pounds per square inch, bent in a U shape, with the ends expanded in cast iron tube-heads. The head is not flat, but conical, as shown in Fig. 7, encouraging the sediment in the water to pass immediately to the discharge mud-blow-pipe outlet.

This is the steam-tube type, with the water inlet high enough at the side not to disturb the sediment, and the water

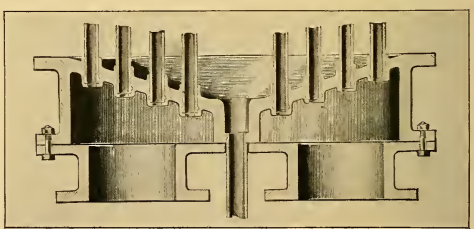


FIG. 7.—SECTIONAL VIEW OF TUBE PLATE AND BOTTOM OF HEATER MADE BY MESSRS. I. B. DAVIS & SON, HARTFORD, CONN.

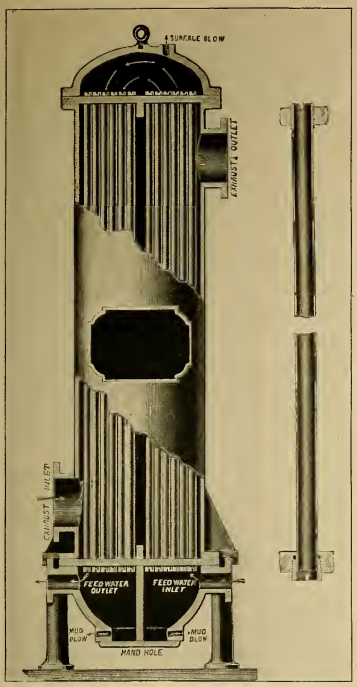


FIG. 8.—HEATER MADE BY THE WHEELER CONDENSER & ENGINEERING CO., NEW YORK AND LONDON

outlet at the proper distance below the top level of the water to prevent the scum going over with the water. A valve is provided for removal of scum.

One of the several forms of Baragwanath heater is known as a steam-jacket heater. The tubes, as shown in Fig. 6, are expanded into tube sheets at the top and bottom. The exhaust steam enters at the bottom, passes up through the tubes, and returns on the outside of the inner shell, the water being between the pipes and the inner shell. The water inlet is at the bottom of the shell, and the outlet at the top. The same makers turn out a horizontal open heater with a screen for separation of oil and trays for sedimentation.

In the Wheeler heater, Fig. 8, there are tube heads at both ends; the tubes are enlarged at one end and made fast by a screw end. The other end is made fast by a brass outer ferrule and asbestos packing, which go in a special pocket formed in the tube head for each tube. The tubes are free to expand or contract, as the ferrule is not rigidly attached to the tube. These heaters also are made with both ends of the tubes with ferrule and asbestos packing. The tubes are made of the best quality of seamless brass, tinned and tested to 700 pounds per square inch.

The Wheeler Company also make a double-tube horizontal heater for marine service. The exhaust steam in this

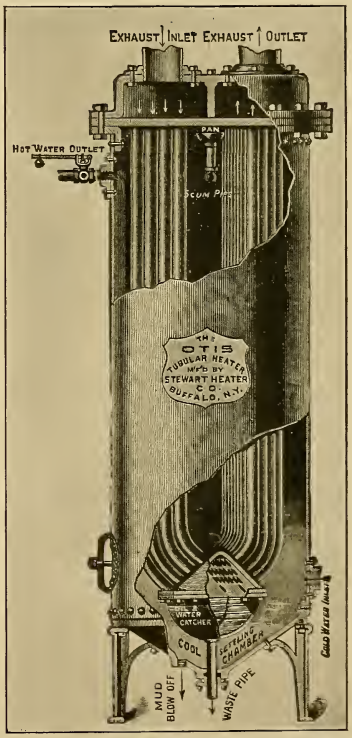


FIG. 9.—THE OTIS HEATER. MADE BY THE STEWART HEATER CO., BUFFALO, NEW YORK

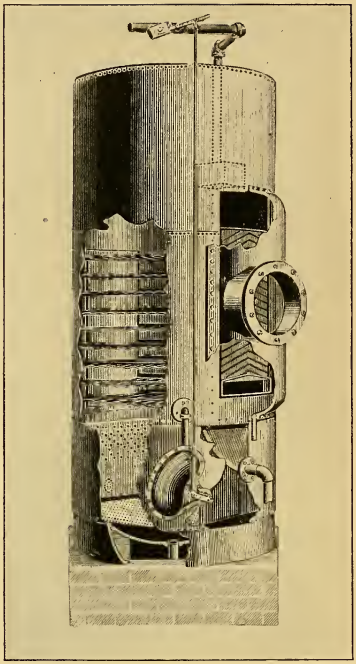


FIG. 10.—COMBINED HEATER AND FILTER. MADE BY THE STILWELL-BIERCE & SMITH-VAILE CO., DAYTON, OHIO

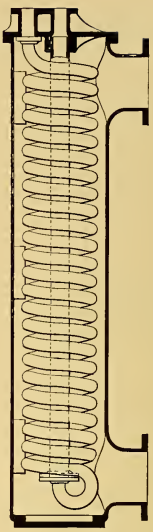


FIG. 11.—HEATER CONSISTING OF COPPER COIL INSIDE OF EXHAUST PIPE. MADE BY MESSRS. YATES & THOM, BLACKBURN, ENG.

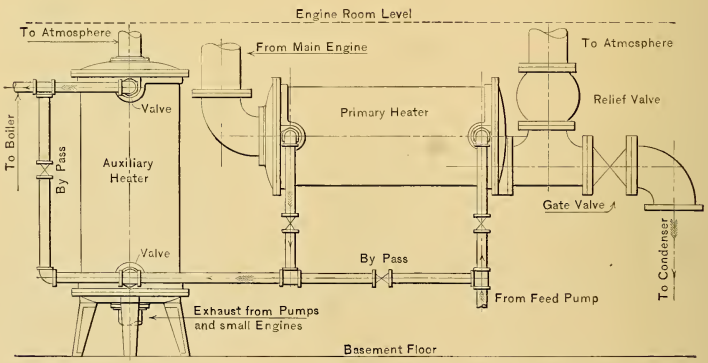


FIG. 12.—ARRANGEMENT OF PRIMARY AND AUXILIARY FEED-WATER HEATERS BY THE WHITLOCK COIL PIPE CO., HARTFORD, CONN.

passes through the inner tubes, then returns through the annular space between these and the large tubes, and then out. The feed enters the shell at the bottom and travels between and about the tubes and then out at the top.

The Otis heater, Fig. 9, is of the steam-tube pressure type, and has a steel shell riveted to a flange connection at the top and at the bottom to a conical hopper. The distinctive feature in this design is the shape of the tube chamber. The condensed water and oil are collected in the bottom of this chamber and drawn off by a pipe passing through the bottom of the heater. The water enters the heater at the bottom and is discharged near the top.

One of the early designs of feed-water heaters is of the coil type. This was developed in Great Britain, and is virtually an enlarged exhaust pipe; in fact, it is a section of the exhaust pipe, from the top of which cast iron body drops a perpendicular feed-water pipe having a copper coil pipe winding upward from its lower end and out through the top head, as shown in Fig. 11. If all feed-water were pure, this would make a very desirable heater, as its principle of long travel of water in ample steam space is good.

The American development of this kind of heater is shown by another line of water-tube heaters, which consist of copper or brass pipe coils bent spirally inside of an outer riveted shell. The Whitlock heater, Fig. 12, is so built, and is composed of a steel shell body riveted to cast-iron flanges, top and bottom, to which the heads are bolted. Inside of this heater, all of whose shell joints are brazed, are copper coils, tested before use to 600 pounds per square inch.

When the heater is used as a reheater between high and low-pressure cylinders of a compound engine, live steam is admitted to the coils, and the exhaust steam to be reheated before passing into the low-pressure cylinder is in the shell.

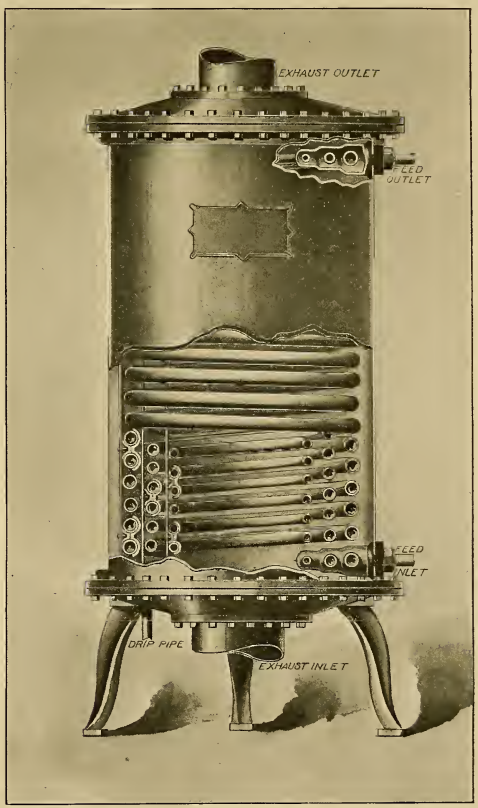


FIG. 13.—PIPE COIL HEATER MADE BY THE HARRISBURG PIPE BENDING CO., LTD., HARRISBURG, PA.

The manner in which the coils of tubing are connected to the feed-water inlet and outlet is distinctive to the heater, and is well shown in the illustration.

In the Harrisburg heaters, Fig. 13,

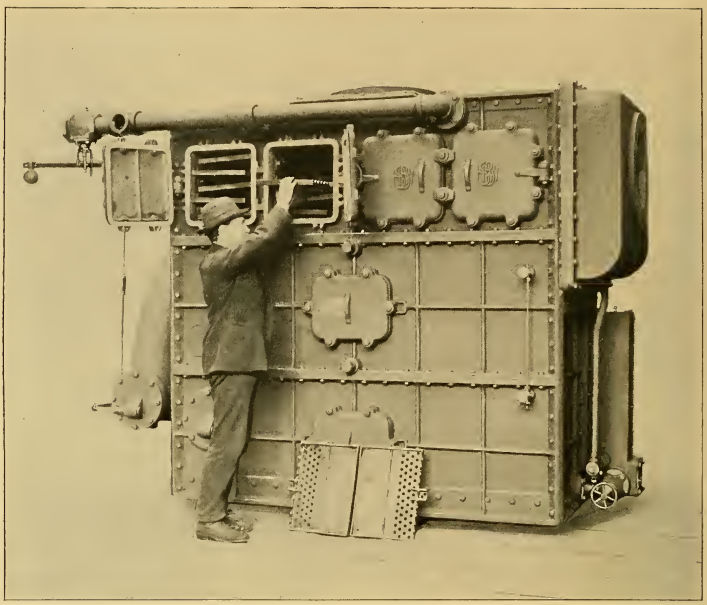


FIG. 14.—A COCHRANE HEATER. MADE BY THE HARRISON SAFETY BOILER WORKS, PHILADELPHIA, PA.

this connection is accomplished by means of a special fitting to which the three or less pipe coils are connected, top and bottom, inside of the shell, and by means of flanges and threaded ends outside the shell the feed pipes are attached.

We now come to the open type, or heaters and purifiers combined. Among these there are, to begin with, the Cochrane heater, which consists of a cast-iron box, made in sections, bolted together at the flanges. The upper part, as shown in Figs. 14 and 15, contains trays with serrated edges to break up the water as it passes down through and over them.

These trays are all set in the path of the incoming exhaust steam, are inclined in opposite directions, and also vary in number and size as required by the work to be done in the heater. The trays are easily removed through the doors provided for the purpose, and are likewise prevented by guides from rattling, apt to be caused by the pulsation of the entering exhaust.

The cold water entering the heater is regulated by means of a balanced valve, operated by a copper ball float in the lower part of the heater. Just above the water level is a skimmer, which is also an overflow, draining to a trap of sufficient size. Below this outlet there is a filter bed of coke. The outlet of feed-water is through this coke, and under a shield which keeps the coke away from the outlet.

The heater is also fitted with an oil separator, glass water gauge, blow off, and all fittings necessary to make it a complete heater and purifier. It is installed with the exhaust issuing from the top of the heater or a vent out of the top, and drawing the exhaust steam through the regular side inlet, wasting

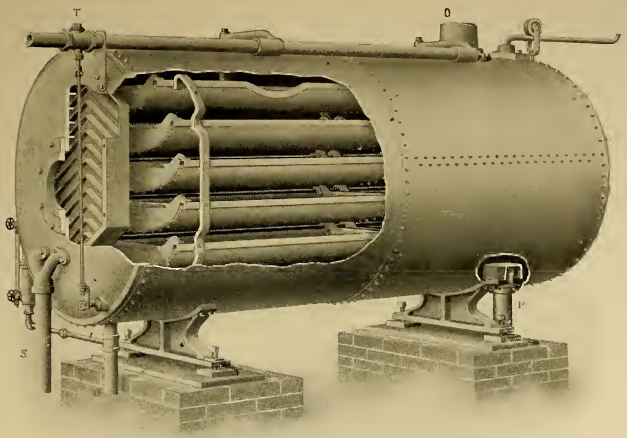


FIG. 16.—HEATER MADE BY THE HOPPES MFG. CO., SPRINGFIELD, OHIO

what is not required for heating. This method is used where there is a surplus of exhaust steam.

The Webster "Vacuum" heater, Fig. 19, is one of the so-called open type; but it is sealed from the atmosphere, so that in case the exhaust steam from the engine decreases from its usual quantity, the heater will draw from the exhaust pipe all that is possible to be obtained in that way, and should the steam be less than is required to produce a certain temperature in the feed-water, a partial vacuum will result, and the heater for the time becomes a sort of condenser. In this type of heater only that part of the exhaust required to heat the feed-water to a certain temperature is passed into the heater.

The standard heater and purifier of the makers is a cast-iron shell, in one piece, with removable cover, wedge-shaped bottom, exhaust inlet near the top, outlet at the top, and fitted with a weighted safety valve. The exhaust

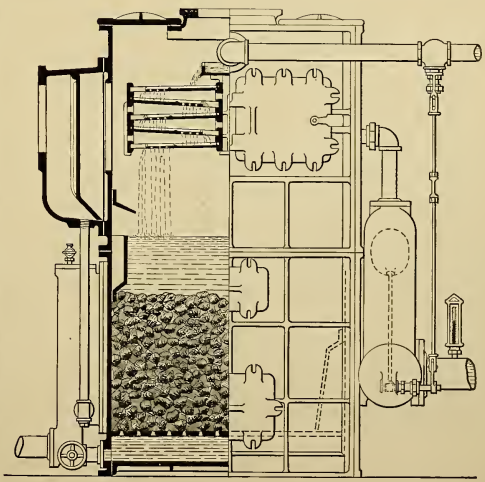


FIG. 15.—SECTION AND ELEVATION OF A COCHRANE HEATER

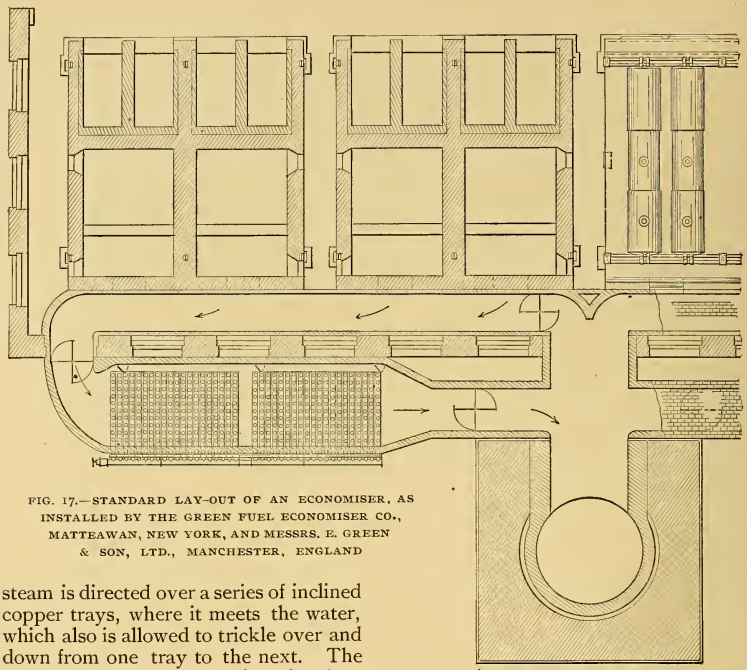


FIG. 17.—STANDARD LAY-OUT OF AN ECONOMISER, AS INSTALLED BY THE GREEN FUEL ECONOMISER CO., MATTEAWAN, NEW YORK, AND MESSRS. E. GREEN & SON, LTD., MANCHESTER, ENGLAND

steam is directed over a series of inclined copper trays, where it meets the water, which also is allowed to trickle over and down from one tray to the next. The water then falls to the settling chamber, at the highest temperature, and from that chamber it is pumped to the boilers.

An apron across the entire settling chamber, in front of the submerged outlet, prevents scum or other light impurities from passing to the boiler. The heater is also made with a filtering compartment to be put in use where the water demands it.

The Hoppes live steam purifier, Fig. 16, consists of a cylindrical shell, in which are arranged horizontal pans, one over the other, so as to be readily removed. These pans receive the feed-water, and, through contact of the steam with the water, the heavier solids settle, while carbonates, sulphates, silica, and other hard-scale substances adhere to the

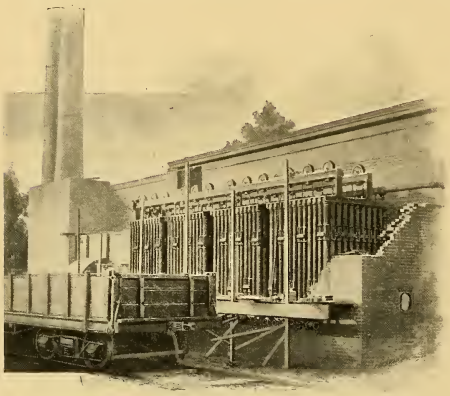


FIG. 18.—A CONSTRUCTION VIEW OF A GREEN ECONOMISER INSTALLATION

under sides. The elastic feature of the trays enables them to be twisted and distorted, and the hard substances can thus be easily removed from them.

The Hoppes heater, though similar to the purifier in so far as the form of the pans is concerned, consists of a steel cylinder, cast-iron heads, easily opened to admit of trays being cleaned. The exhaust steam, after passing through an oil separator, enters the heater at the rear end and leaves the shell at the front,—that is, such portion of it as has not been condensed. The makers say of it that it does not require any filter for the water, the latter being sufficiently purified for boiler use by the removal of all solids within the heater.

The Stilwell heater and purifier, Fig. 10, is similar in its operation to the other open heaters. It is built with a riveted steel shell, and is equipped with flat strainers, located midway of its height, with a filtering chamber at the bottom. Steam is admitted to a cast-iron hood-piece opposite the trays, which also aids in separating the oil from the exhaust steam, and forms a pocket at its base where the oil collects and can be drawn off. The water is drawn off at the bottom after having passed through the filtering material.

In connection with all heaters this table may be of interest, showing the temperatures at which calcareous matters are precipitated in ordinary boiler waters:—

Carbonate of lime	176–248° F.
Chloride of magnesium	212–257° F.
Sulphate of lime	284–424° F.
Chloride of sodium	324–364° F.

The rating of a pressure heater is a matter on which little has been written, but a common rule for a pressure heater is 3 square feet of heating surface for one boiler horse-power of water, heated to 200-210° F. In designing a heater, however, the heating surface should be made large enough or ample to transmit the maximum number of heat units per unit of time, and then the water velocity should be adjusted to suit the capacity required. One heater manufacturer uses 350 B. T. U. as the maximum transmitted; some types of heaters would need only 150 to 200 B. T. U. as the maximum. For open heaters

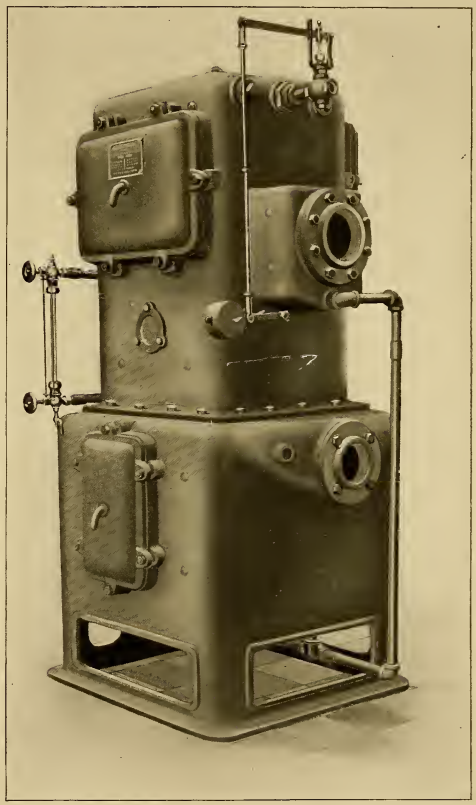


FIG. 19.—FEED-WATER HEATER, PURIFIER AND FILTER. MADE BY MESSRS. WARREN WEBSTER & CO., CAMDEN, N. J.

the capacity is limited only by the amount of steam and water that can be brought together in a unit of time and thoroughly mixed, and is necessarily determined by the experience of the maker with results obtained from his own machine.

What is known as the fuel economiser is somewhat different in function from the several heaters thus far considered, in that it utilises the waste heat of the furnace gases before going to the chimney instead of the waste heat of exhaust steam. It is a section feed-water heater, consisting of a great number of cast-iron tubes or pipes, about 4 inches in diameter by 9 or 10 feet long, set in rows, and connected together with the necessary headers. The water is pumped into them at the locality farthest from the boiler uptake and taken out where the gases are the hottest.

Each tube is provided with a geared scraper which is moved up and down the outside of the pipe, removing all soot as fast as it accumulates. This work is accomplished by means of a separate engine or motor. The power required is small. The tubes are tested, or should be, to a pressure of 500 pounds per square inch, as the water, in some instances, passing through them, is at boiler pressure. The whole apparatus is enclosed in a brick wall or other non-conducting covering. The pipes should be blown off once each day, as the scale will accumulate in them, and they should be given as much, if not more, care than other feed-water heaters. In Figs. 17 and 18 two Green economiser installations are shown.

Economisers in no way alter the conditions in the boilers of plants of which they form a part, but they materially add to the efficiency of the entire plant. From one plant the writer has taken these figures: —

Boiler horse power	1,200
Heating surface in economiser	6,400 sq. ft.
Flue area for economiser	6,400 sq. in.
Economiser tube surface per boiler h. p.	5.33 sq. ft.
Cost erected per sq. ft. of economiser surface	80 cents
Cost erected per h. p. of boilers	$4 to $6

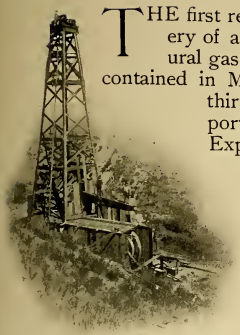
In setting economisers, whether in connection with a chimney or a fan, it is always with a by-pass flue, so that the gases may be passed direct to the chimney or through the economiser to the chimney, as may be desired.

The draught in a chimney is reduced by the addition of an economiser, for the flue gas temperatures are delivered to the chimney at about 265 to 300° F., or even lower, and chimney draught is a function of temperature of the gases.

Water is heated in an economiser to a much higher temperature than in a steam feed-water heater, this temperature depending only on the temperature at which the gases leave and enter the apparatus.

NATURAL GAS IN ENGLAND

By Inverness Watts



THE first record of the discovery of an inflammable natural gas in East Sussex is contained in Mr. Henry Willet's thirteenth quarterly report of the Subwealden Exploration (Netherfield), 1875. It is stated that in making experiments on the temperature in bore holes at various depths, and on lowering a light into the bore-tube, an explosion occurred.

Another discovery of inflammable gas occurred in the year 1895, when a deep artesian bore-tube, 6 inches in diameter, was sunk in the stable yard of the new Heathfield Hotel, close to the Heathfield station of the London, Brighton & South Coast Railway ,in the parish of Waldron, East Sussex. At a depth of 228 feet the foreman of the work noticed that the water which had been put down the bore hole to assist the working of the tools was "boiling." As he was about to lower a candle to discover the cause, the gas arising from the bubbles caught fire, and burnt "to about the height of a man." Subsequently the foreman attached small tubes and ignited the gas at a distance of fifteen yards from the bore hole. Although he appears to have reported the details of the strata traversed to his employers, he does not seem to have reported the discovery of the gas. The boring was not carried any deeper, as no water had been discovered.

The third discovery was made in 1896, at a site about 100 yards distant, on lower ground than the last, in the railway cutting between the north-eastern end of Heathfield railway station and the mouth of the tunnel, by the side of the permanent way. The railway company desired to obtain a better quality of water for their engine tank than that afforded by the present surface-spring supply. Accordingly a 6-inch bore-tube was sunk, commencing at the bottom of a sump 73 feet deep, into which the surface water had been allowed to flow. Gas appears to have been discovered a long time before its inflammable properties were tested, a strong odour of gas having been noticed for some days; but the smell was attributed to the presence of "foul air" in the bore-tube.

At a depth of 312 feet from the level of the permanent way the smell and rush of the gas were so pronounced that (by way of experiment) someone applied a lighted match to it, when a body of flame sprang up, the height of which is variously stated, the maximum estimate being 16 feet. It was extinguished with great difficulty, by means of damp cloths thrown over the mouth of the tube. The gas continued to increase during the remainder of the depth bored. The boring was abandoned at a depth of 377 feet, no useful amount of water having been obtained. The wrought iron tubes were withdrawn from the bore-hole, with the exception of one length, which still remains in the ground, the tube being continued upward to near to the top of the sump. A cast-iron cap has been screwed on to the top of the bore-tube, with a ½-inch bend and stop-cock affixed thereto, and Heathfield station has been lighted throughout by the gas from this boring since 1898, consuming about 1000 cubic feet each night.

The immense force with which the gas sometimes finds a vent through some artificial boring is, perhaps, due

BORING FOR NATURAL GAS AT MAYFIELD STATION

to the two causes which are ever present,—the internal heat of the earth causing an expansion in volume, and the hydrostatic pressure due to bodies of water counteracting to lessen this expansion. The usual specific gravity is little more than that of common air, and, from the examination which has been made, it may be fairly concluded that the gases obtained from the deeper strata are of a higher specific gravity, are richer in the carbon element, and possess greater illuminating power. According to a paper published in the *Quarterly Journal* of the Geological Society on the discovery of natural gas at Heathfield, the pressure cannot be less than 135 pounds per square inch, and in more recent borings, put down by the Natural Gas Fields of England, Ltd., the pressure is as great as 200 pounds to the square inch.

One of the first things done by the Natural Gas Fields of England, Ltd., after concluding their agreements with the London, Brighton & South Coast Railway, was to instal a 1½ H. P. gas engine, worked by natural gas, to pump the water for use of the locomotives passing through Heathfield. This small engine has ever since satisfactorily performed the work previously done by a steam engine. The consumption of natural gas per I. H. P. equals 15 cubic

feet, whereas with London gas from 20 to 25 cubic feet are needed.

Since the Natural Gas Fields of England, Ltd., commenced their operations at Heathfield great strides have been made. The country for many miles round has been thoroughly surveyed by geological experts, both English and American. The reports of these gentlemen are unanimous that the south of England promises to be a larger field than any America has yet known; and when one considers the gigantic advances which have been made in that country by its uses, the importance of it to Great Britain cannot fail to be realised. Within the last twelve months the question of utilising the natural gas known to exist has attracted more and more interest. A great advance in the matter of distribution is the high pressure at which the gas issues from the borings. This pressure, taken at its minimum, 120 pounds per square inch, is more than sufficient in itself to carry the gas to any large city in England.

Another advantage which English natural gas has over the American is that whereas the latter, when burnt in a fish-tail or Argand burner, has practically no illuminating power, the former, when burnt under the same conditions, cannot be distinguished, save by an expert, from the ordinary coal gas in common use.

It is certain that England will take advantage of the experience of America and lose no time in utilising the supply of natural gas now proved to exist. When compared with London coal gas, burnt in a standard Argand burner, Heathfield gas gave an illuminating power equal to fourteen candles, against sixteen candles of the London gas; when burnt in an incandescent burner (the light which depends entirely upon the heat of the gas), the gas, as tested at Heathfield, gave 20 per cent. more light than did coal gas under the same conditions. Both these tests were made with the natural gas exactly in the same condition as it issues from the boreholes, without any purifying or enriching whatever. Analysis has shown its composition to be:—

	Per Cent.
Methane	93.4
Ethane	3.0
Nitrogen	2.7
Carbonic acid	0.9
	100.0

Apart from the bore hole on the Brighton Company's property at Heathfield station, six other borings have been put down, and gas has been struck at about the same depth and pressure as at the station well. Further, it has been proved that the pressure of gas at any one of these wells remains the same whether the other five are open or capped down, showing that one well does not draw off from another.

At Mayfield, five miles away, there are two borings, at one of which gas has been struck and burnt just recently. At the other, gas-bearing beds were undoubtedly gone through; but at the time, the boring being full of water, the gas was not lit. This boring is now being further developed, with a view to proving the existence of gas in an older formation than that which has at present been tapped. At a depth of 500 feet in this boring a considerable quantity of petroleum was struck, the sand pump being filled each time it was lowered.

The company has also a boring at Netherfield, near Battle, where it is shortly expected that gas will be struck, as on this spot about twenty years ago gas burnt from a boring for some months, as some of the workmen engaged on this old boring, still living in the place, can testify. Some of the gypsum found in boring at Netherfield is saturated with petroleum. A boring was also recently commenced at Ticehurst Road station, on the South-Eastern Railway.

The Natural Gas Company have acquired large areas of freehold land suitable for factory purposes, to be supplied with gas both for lighting and power purposes at a few pence per 1000 cubic feet. Already many large manufacturies are on the point of being started. The ironstone in the district is exceedingly rich, and it was only on the discovery of coal in the north that the iron industry left Sussex. It is a fact that in the eighteenth century over 60,000 hands were employed in the iron

HEATHFIELD STATION, WITH GASHOLDER ON THE LEFT

industry in Sussex. Most of the early cannon were cast at Heathfield and Mayfield. The possibilities of natural gas for glass manufacture are also important, as a large quantity of sand can be obtained at Heathfield containing 95 to 98 per cent. of pure silica. Several glass manufacturers are already arranging to commence operations there with the new fuel.

THE UNITED STATES STEEL CORPORATION

ITS PHYSICAL DEVELOPMENT AND ORGANISATION

By George Ethelbert Walsh

THE publicity given to the financial organisation and equipment of the United States Steel Corporation has, to some extent, overshadowed the physical development and work of that giant establishment, and, while many can quote readily the figures of the bond issues, salaries of the leading officers, and expenditures made to secure control of rival companies, comparatively few could enter into any detailed explanation of the system of administration which has made it possible for this corporation to successfully conduct its business. There is something fascinating and picturesque in dealing with figures which run up into the millions, and the financial organisers of the great steel corporation have had their share of the glory; but it is safe to say that the men who have made the company yield interest on the money invested deserve more credit than they receive.

It is about two years now since the

mammoth concern was formed, and in that time the work of equipping and manning the different plants has been going on steadily and continuously. While others managed the financial end of the concern, the officers of the different plants, experts in steel making, engineers, students of transportation problems, and mechanics, have been working to improve the physical condition of the property so that it would yield the maximum of profit. No other organisation ever presented so many serious problems to overcome. The fear that the corporation would prove top-heavy and unwieldy has been effectually disposed of by the last quarterly statement of profits. There has been a continuous advance in the profits since the first quarterly statement, and each succeeding one was a surprise to the world, and particularly to those who predicted the early collapse of the corporation.

In order to find the reason for this it is necessary to study some of the economies effected by the corporation in its manufacturing methods. The object of the consolidation was to reduce cost of manufacture by introducing economies in transportation, in works practice, in mining, smelting, and selling. The system required to accomplish this had to be as far-reaching and comprehensive as the corporation itself. A good deal of the millions of dollars at first invested were for the purchase of properties that were already found to be in profitable working order, but in the past twelve months the investments have been more directly in the line of improving old plants or constructing new ones with all modern machinery for better work. The physical improvement that has been made in the corporation's property has thus added to its actual value, though it does not figure in the quarterly reports. This is made apparent in numbers of ways, and one has only to visit some of the plants to realise it, or to make a study of the whole system of plants by which the corporation equalises matters so that each one is made to come up to a certain standard of efficiency in order to retain its individual existence.

In order to appreciate the size and scope of the business, a few figures are interesting as showing something of its physical nature. Its property is scattered over a wide section of the country, extending from the Great Lakes to the Atlantic seaboard, and from one coast to another. It controls and operates over 105 mines, located in five of the greatest mining regions of the United States. Last year these mines had an annual output of 14,000,000 tons of ore. The total output of finished steel for the same length of time by the corporation was about 8,000,000 tons. Besides the ore mines the corporation controls a number of valuable coal mines, some of which have been worked only since the coal strikes of last winter. Since then new coal mining regions have been bought up by the corporation for another such emergency. The money thus invested may remain idle for a number of years, unless another serious coal strike should threaten to handicap the company in its operations; but whether the coal mines are worked or not, they will enhance in value as time goes on.

The corporation owns or controls 1200 miles of railroads and a fleet of nearly 125 steamships, barges, and other craft. Last year the number of men employed approximated 170,000. The average wages paid to this large army of employees amount to nearly $702, and the total pay-roll was over $119,000,000. Although owning railroad lines, steamships, barges, and other ships, the corporation last year paid to outside transportation companies over $54,000,000. This amount represented, to a large extent, expenditures for double transportation, which the new improvements will in time avoid.

As an illustration of this the 8,000,000 tons of finished steel produced must in many instances be handled four, five, and even six times before it is finally sold to the consumer. The transportation of the ore to the blast furnaces, and the iron to the converting departments and rolling and finishing mills, will add to its cost twofold if the different mills are widely separated. The coke, coal,

ore, and limestone must first be transported in bulk to the blast furnaces, and in the past most of this material has been handled two or three times before it was ready for use. Consequently, it is estimated that the 8,000,000 tons of finished steel represented the handling of a total tonnage of over one hundred millions.

In the equipment of the organisation the question of economising in transportation was one of the first considered. It was estimated that a million dollars a year could here be saved by the introduction of new machinery for loading and unloading ore, coal and limestone. One cent per ton reduction in the cost of handling would save this amount for the stockholders. But the question of reducing the cost of handling was more complex than simply seeking lower rates per ton from the transportation companies.

The plans laid by the managers of this department have constantly aimed toward such physical improvements of the property as would make a reduction in cost of handling a permanent factor in the company's work, and independent of all private railroads and steamship lines. The building and equipment of branch roads from mines to blast furnaces, and from furnaces to finishing and rolling mills, have been continuously carried forward, and within a few years the total mileage of the company will be nearly doubled. The equipment of the docks and mines with labour-saving devices, such as loading and unloading scoops, elevators, and self-dumping cars, cranes, derricks, and automatic car lifters, are all a part of this general plan. So great has been the economy in this line by means of mechanical ore and coal handlers that a saving of fully 25 per cent. in the cost has been effected. This alone means an annual profit over old methods of a vast sum of money. The amount invested in the labour-saving devices is small in comparison to what is saved.

The transportation problem further became involved in the relative situation of mines, mills, and markets. When the company first secured control of its scores of different plants, they were scattered widely over the country, and it was easily demonstrated that, for economy's sake, many of them should be permanently closed and others greatly enlarged. The problem confronted was how to centralise the profitable plants so that transportation of ore, coal, coke, and limestone between mines and furnaces and mills could be reduced to the lowest possible cost. This was not so easy to accomplish as to introduce new labour-saving machinery. A system of individual transportation by rail and steamship was gradually built up by the corporation, and this is being extended from year to year.

Coal mines were directly connected with the ore mines, and around the latter blast furnaces were erected to reduce further the cost of transportation. Coke and limestone furnished important items of transportation, and even to-day they are no inconsiderable items in the cost of the finished steel. A further economy was obtained by opening some of the mines which were so favourably situated that coal and iron ore could be obtained in abundance within a radius of ten miles of each other. A few of the old mines, which, while rich in ore, presented difficulties of transportation, were temporarily closed. It was considered economy in operation to expend more money in buying new mines which promised to reduce the cost of production and operation for an indefinite time. Thus millions of dollars were expended in acquiring new mining property, when to many it seemed as if the corporation actually controlled far more mining land than it would ever be able to use.

The wisdom of this operation was made apparent in the past year, for it has been demonstrated that some of these new mines yield double the profit of the old ones, and the cost of operation is reduced to a minimum. Another matter which received early attention was that of systematising the cost of production in the different mills so that each one would come up to a certain standard. It was impossible for the low-grade ore of some mines to be shipped a great distance, as in the past, and be converted into finished steel at a cost as low

as that attainable with the rich ores of another mine that did not have to be transported far. From the same mine rich and low-grade ores would be obtained, and the latter would cut down the profits of the former to a great extent. It was not considered policy to close the mines that had low-grade ores, nor to abandon that portion of the good mines which yielded lean ores. But it was found that by shipping the low-grade ores to nearby plants and the rich ores to the distant ones an equalisation of cost of production could be obtained which would show a general average of price. By this method the several plants have nearly equal opportunities to show certain percentages of profit. There is instilled in the manager of each one a wholesome rivalry to exceed all others in the year's record. Instead of stifling competition, the corporation has encouraged a strong impetus to rivalry, and each plant endeavours to make a better showing in the company's books than any other. This system of competition has already engendered pride and respect among employees for their different plants, and the quantity and quality of the individual output are carefully and jealously guarded.

The system of keeping a comparative record of the cost of a ton of steel in the many different plants has been evolved after long study and tests, but so accurately does it work to-day that the officers can see at a glance any weak points in the whole series of establishments. The quantity and quality of the material delivered at each mill become matters of record, back of which even the superintendent of the mill cannot go, and the cost for producing a ton of steel shows in the expenses of operation and the total output. The cost of the material, including mining, transportation, and handling, is given to each mill superintendent, so that he knows exactly upon what he is working, and if another mill makes a greater output it may be due to superior natural advantages or other causes, and not the result of better management. Each mill superintendent in this way is placed upon his own individual ability to excel another superintendent in producing steel.

New plants are being continually added to the corporation's property, both by direct purchase and by building operations. The whole country has been carefully examined, and it has been found that not all the plants are located as favourably as they should be. This progressive tendency of the company is a factor which promises much for the future. There is no attempt to stifle growth by operating mills at little profit when an expenditure of a few more millions in another section would completely turn the tide. The company has always been willing to abandon the most expensive plants when it could be shown that they were not earning a fair interest on the capital. From the first the corporation lacked sufficient blast furnaces to accommodate its expanding trade. By the purchase of the Union Steel Company's plant last winter the corporation immediately secured seven blast furnaces and a large number of open-hearth furnaces. As these furnaces were needed more than capital by the corporation, they served immediately to effect an important economy of operation. Before that the corporation had to draw upon the blast furnaces of private companies for the pig-iron which they needed for immediate use.

At the same time valuable coke properties were secured in the Pennsylvania iron regions, where new blast furnaces are now in the course of construction. Primarily these coke lands were valuable in their ultimate possibilities, but there were apparently no customers anxious to buy them. They have become immediately and productively valuable under their new ownership, and are to-day rapidly undergoing a change in character which will make them, in the near future, important centres of a great industry.

The work of introducing economies in the blast furnaces has received fully as much attention as the transportation problem. The furnaces are enormous consumers of fuel. A few attempts were made to save the waste of gas escaping from them, but it has only recently been shown that this waste gas, if used in gas

engines, can be made more profitable than the pig-iron itself. This appears like a complete revolutionising of a standard industry, and to a large extent it is. Gas engines to-day can supply electric power to operate factories and mills in all directions, and in nearly all the new blast furnace plants erected by the steel corporation provision is being made to utilise the waste gas in such engines.

The modern steel mill uses electric power more than ever before, and if the cost of this power can be reduced it will directly affect the cost of the finished steel. Gas engines of large power, coupled to electric generators, are now being installed in connection with the company's new blast furnaces to furnish power for miscellaneous service in the various works. The furnaces and the finishing steel mills will in all probability become knit closer together than ever before as a consequence. The fuel required for the blast furnaces will supply nearly sufficient power for all the subsequent manipulations.

Some of the new gas engines which have been installed by the United States Steel Corporation are from 500 to 700 effective horse-power. To make 150 tons of iron a day, a blast furnace will generate about 21,000,000 cubic feet of gas. About 88,000 cubic feet of this low-grade gas consumed per hour will yield 700 effective horse power. If the full amount of gas generated in making the iron is discounted by one-half for heating the blast for the furnace, there would still be sufficient left to produce some 3500 effective horse-power generated by the gas engines for other uses. Thus in every one of the company's blast furnaces there is a possible saving to-day of more than 50 per cent. over the old method of producing pig-iron. The same amount of waste gas, used under the boilers for steam raising, would produce hardly 1000 horse-power. The gas engine in connection with the blast furnace is thus a factor which makes itself felt powerfully in the industry, and promises within a few years to add greatly to the profits of pig-iron making, or to decrease its cost far below present prices.

This economy, however, is not peculiar to the steel corporation or its properties. It is one of those revolutionising tendencies which have always been observable at different periods in the industry when some inventor or discoverer has shown the way to new and cheaper methods of manufacture. The same changes were effected when Bessemer introduced his method of steel making; later the open-hearth system caused another revolutionising improvement. At present the gas engine is a powerful factor in the iron and steel industry of which it would be difficult to measure the future correctly at this time.

The plans of the company have been from the first to supersede hand labour by machinery where and whenever possible. The best engineers have been employed to improve the properties of the company as far as possible by the introduction of devices for automatically operating the plants, and the leading mills of the corporation have been equipped with machinery met nowhere else in the world. They are sometimes the product of the local engineer's mind, who has endeavoured to save time and labour with some device of his own.

As a matter of comparison it may be said that in several of the company's largest plants 4000 men daily produce twice and three times as much steel as the famous Krupp Works in Germany do with 15,000 men. The difference is simply in the method of work. In the former, machinery takes the place of men, and in the latter, hand labour is so cheap that little attempt has been made to devise means and methods to do the work for the men. The results in the two cases are wonderful. The machinery doubles, trebles, and quadruples the output, and the profits mount higher in proportion.

The management of the Steel Corporation's mines is a department equally developed and progressive. The consolidated mines produce ore of widely different values, and each mine is compelled to furnish its quotum toward the earnings of the company. Last year millions of dollars were thus daily accredited to the mines, and they fully

deserved it because of the economical methods of management. The cost of raw material at each mine is carefully ascertained, and then through its devious wanderings until consumed by the blast furnace, account is kept of its increasing expense. The mines are operated by the most improved machinery, and every possible economy has been attempted.

The fleet of steamers carrying the ore work continuously, sailing from the nearest port of the mines to the nearest steel plant using it. The steamers keep the supply continuously ahead of the demand, and the mills are never forced into idleness through lack of raw material, whether it be ore, coal, coke, or limestone.

The mills, transportation lines, and furnaces are all brought under one harmonious system which enables the most efficient results to be obtained with a minimum expenditure of energy. The greatest aggregation of capital ever brought together in the history of the world is carefully distributed among the mills, railroad and steamship lines and mines so that each division must show an earning capacity. Great as the financial reorganisation of this giant company may have seemed, the systematisation of its working power and the development and improvement of its physical properties are far more deserving of public approval. It has required a period of nearly two years to show to the world what could be accomplished by such concentrated endeavour. The visible proofs of it are most effectually shown to the investing public in the published reports of quarterly earnings; but to appreciate the inside workings of this mammoth enterprise one must study the mills, mines, and transportation lines as they are to-day, and as they were before the organisation.

The heads of the various departments are held responsible for different parts of the system. The mines, railroads, steamships, and different mills are controlled by different heads, who, together, form a sort of cabinet with the president of the company. Every part of the works is thus held into close touch with every other part. The policy of a single mill cannot be changed without the consent of the president and his cabinet. Each head is required to produce the greatest amount of finished steel at the least cost, but this must be done through efficiency of work and methods rather than through cutting wages or underbidding others in buying raw material. These are fixed charges which cannot be changed at the individual option of one mill.

COLEMAN SELLERS, E. D., Sc. D.

A BIOGRAPHICAL SKETCH

By Dr. Henry Morton. A Posthumous Publication

On April 9, 1902, Dr. Morton, in a letter to the editor wrote:—"I expect to 'go into hospital for repairs' on the 14th and to be laid up for about four weeks. At present the biographical notice of Coleman Sellers, asked for by you, is so advanced that it will be easy for you to get it into shape with the aid that will be given to you by Dr. Coleman Sellers' son, Coleman Sellers, Jr., who has, in fact, had my manuscript in his hands for some time, to fill up some gaps in the descriptive matter and to supply drawings, etc. I hope before the 14th to put in your hands most, or all, of the manuscript, and then leave you and Coleman Sellers, Jr., to work up anything which may be required. I write now as I may be hurried at the last."

To the great sorrow of a wide circle of friends, Dr. Morton did not recover from the effects of the surgical operation to which he submitted himself. Death came within a few weeks after the writing of the above lines, and his biographical sketch of Dr. Sellers thus has an added, pathetic interest as being the last work in a long and exceptionally fruitful career.—*The Editor.*

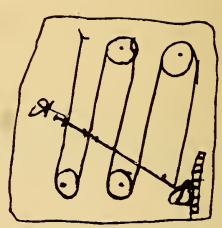
AMONG the men whose genius has contributed to human progress in art, industry or letters, there are some whose mental power appears to be a sudden creative development, not traceable to any ancestral source, while others seem to come by it through inheritance, their predominant capacities appearing to be the result of a natural evolution through a series of generations.

In those of the first class we frequently see combined with marvelous capacities in some one direction a lack of breadth or reach in others, such men, as a rule, being eminently specialists. Where, on the contrary, the influences of heredity are noticeable, we are more apt to find individuals whose mental power is broadly developed and capable of dealing successfully with problems in a wider range of thought. Though such men, from circumstance or environment, may become specialists, they are not limited to their specialties, but evince an aptitude for knowledge in various directions and accomplish useful work in many fields.

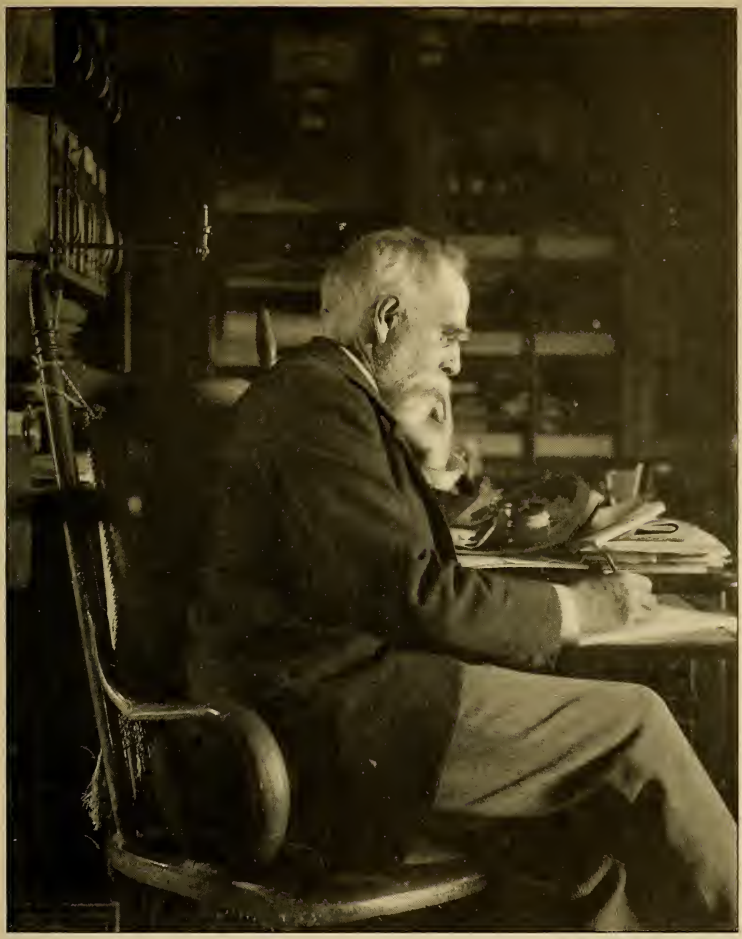
Of this latter class Dr. Coleman Sellers is a notable example, both as regards his antecedents and his mental characteristics. His progenitors, for at least five generations, were men of marked mental activity and mechanical aptitude, and it might almost be said that his career came to him by inheritance. His early education was conducted at private schools in Philadelphia until 1838, when, at the age of eleven, he entered at the Academy of Anthony Bolmar at West Chester, Pa. There his interest in natural philosophy was first stimulated by the simple experiments illustrating the lectures delivered to the students, and the trend of his mind at this time is indicated by the entries in a diary, from which the following passages are extracted as examples: —

NOV. 3RD, THURSDAY, 1842.

Began to make a hygrometer; it is made of cat-gut on which the atmosphere acts, expanding and contracting it, thus moving an index which shows



the degrees on a plate. I have been thinking of making one of a piece of ash which, by expanding and contracting, works compound levers which are joined to the index; thus by a slight difference in the wood a great difference will be perceived in the position of the index; it is to be made pretty much on the same principle as those instruments which show the expansive power of metals, only instead of metal a piece of ash is used in the body



DR. SELLERS IN HIS STUDY

to be expanded, and instead of being acted upon by the heat it is to be acted upon by the atmosphere.

NOV. 4TH, FRIDAY.

At work at my hygrometer, but could not complete it for want of tools. Made an improvement in the instrument; instead of having a weight fastened to the cat-gut I intend to put a spring in this manner. A B is the spring fastened to the frame at A and moving with the index at B. The benefit of this is, that the instrument will work in any position when, if there was a weight fastened to the string, it could only work when in a perpendicular position.

NOV. 8TH, TUESDAY.

Did my first sums in trigonometry to-day; find it pretty easy. Began to read Waverly by Walter Scott. Began to make a machine to show that a weight dropped from the mast of a vessel while in motion will take a diagonal direction in its descent and fall at the foot of the mast.

His intense longing at this time for information in natural history, natural philosophy, and chemistry, was not satisfied by the lectures that were de-

livered to the scholars by a local doctor of medicine. Wanting the assistance of the best text-books, he was compelled to pursue unaided such studies as botany and mineralogy, while to gain all the possible good from the meagre lectures on physics and chemistry, he spent, as the quotations from his diary indicate, much of his spare time in making apparatus to illustrate the facts and theories imperfectly taught in the lecture room.

He completed his course at Bolmar's Academy in his seventeenth year, and

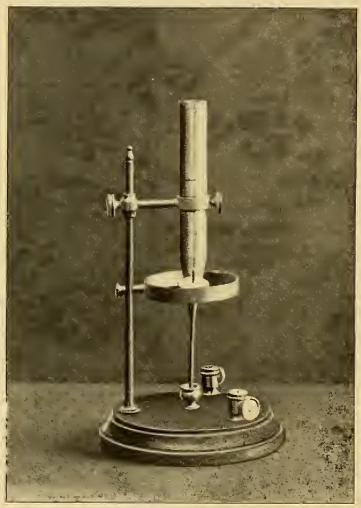


FIG. 1.—INSTRUMENT DESIGNED TO ILLUSTRATE FARADAY'S TANGENTIAL FORCE OF MAGNETISM. MADE BY COLEMAN SELLERS WHEN TWENTY YEARS OLD

as his mother wished him to become a farmer, he devoted the next two years to practical agriculture; but even on the farm his mechanical bent asserted itself, and, among other devices, he contrived and drew a metal-toothed hay rake, mounted on wheels, which antedated the machine now so generally used, but then unheard of.

In 1846, at the age of nineteen, he was offered employment in the Globe Rolling Mill, in Cincinnati, Ohio, operated by his elder brothers, Charles and George Escol Sellers. There his first work was the preparation of a set of drawings of the improved machinery of a mill for Horatio Allen, of the Novelty Iron Works, of New York. When these drawings were completed, he applied himself diligently to acquiring knowledge of all the processes incident to rolling merchant iron, wire rods and the flat rails used at that time on the railroads of the West. Connected with the establishment was quite an extensive wire mill which underwent some improvement under his direction, and while engaged in making wire for O'Reilly, who was then called the Telegraph King of the West, he procured from him a few cells of the battery used on the telegraph outfits of the day and filled his spare time in repeating the experiments that had been announced by Faraday and others, making all the apparatus required for these electrical experiments with neatness and precision. (Fig. 1.)

The writer's intimacy with Dr. Sellers came about through his desire to see a piece of apparatus built by him at this time, which was a modification of one of Faraday's discoveries. He also made several of Dr. Locke's hand levels, when this useful instrument was first proposed by Dr. Locke, with whom he was intimate.

He gathered around him a small coterie of men interested in science, who looked to him to explain and illustrate the new discoveries as they were announced from time to time, and thus we find him, at the age of nineteen, lecturing informally to his friends on Faraday's experiments, and even elucidating Swedenborg's *Principia*. Botany, mineralogy, and conchology, in a country where the streams were filled with interesting shells, gave an object to his rambles. and made him the more observant when engaged in the preliminary survey of a railroad from Covington to Lexington, Ky., afterwards known as the Kentucky Southern. The limestone rocks of Cincinnati's numerous hills were rich in small fossils, and his collec-

tion included many perfect specimens.

Before Dr. Sellers reached the age of twenty-one he was superintendent and manager of the Globe Rolling Mills, and during 1850 and 1851 he was engaged by his elder brother in building locomotives of the latter's invention for use on the Panama Railroad. Upon the completion of these engines, late in 1851, he went into the service of James and Jonathan Niles, became foreman of their locomotive works in Cincinnati, and retained this position until 1856, when he accepted an offer from his kinsmen, William Sellers & Co., of Philadelphia, to take charge of their draughting room. His experience as a locomotive builder had strongly impressed him with the demand that then existed for better machine tools to reduce the cost of locomotives and improve the quality of the work, particularly the need of special tools designed for that service, and he found in his new business ample opportunity to work out his ideas and to further develop and apply his ability as an engineer and inventor.

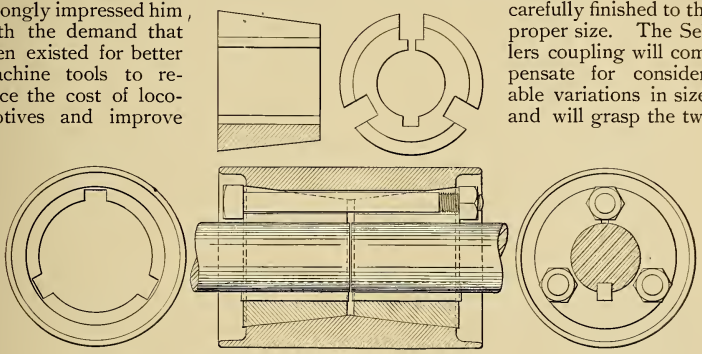


FIG. 2.—THE SELLERS DOUBLE-CONE SHAFT COUPLING

He retained this position for over thirty years, during which time he designed a great variety of machinery, covering all the usual machine tools and a large number of special machines for various purposes, his firm having constructed at different times many mechanical appliances not strictly classable as machine tools. In this way he extended his experience over a large field, embracing a great variety of hydraulic machinery, cranes, hoists and elevators, presses and forging machines, engines, pumps, and injectors, turn-tables and pivot bridges, and much else.

All of his work was characterised by originality, correct mechanical design, and unusual elegance of outline. His originality is amply attested by the long list of patents which bear his name, alone or associated with others. Among his best known early inventions may be mentioned the double-cone coupling for shafts (Fig. 2), which was probably the first successful substitute for the flange, or plate, coupling, previously in exclusive use. The flange coupling must be pressed on the end of the shaft, which, in turn, must be carefully finished to the proper size. The Sellers coupling will compensate for considerable variations in size, and will grasp the two shafts with equal force and maintain correct alignment even where there is an appreciable difference in the diameter of the coupled shafts. The invention of this coupling made a radical change in the manufacture of shafting, cheapening the cost of production and greatly facilitating the expense of installation and repair. It also stimulated a number of inventors to produce other devices for the same purpose. In 1873 Dr. Sellers was admitted to partnership in the firm of William Sellers & Co.

While actively engaged in the arduous duties which fell to his share as chief engineer of a large and growing concern, Dr. Sellers still found time for a

great deal of work of a scientific character, much of which was suggested by questions that arose in his business. In 1858 it occurred to him that the new art of photography, then beginning to supplant the ambrotypes and daguerreotypes, might be applied to illustrate machinery for advertising purposes, and portrait photographers were employed to make the necessary negatives. Their efforts were very unsatisfactory, and Dr. Sellers, concluding to learn the process, took lessons from a peripatetic operator, and soon acquired considerable skill.

FIG. 3.—KINEMATOSCOPE FOR EXHIBITING STEREOSCOPIC PHOTOGRAPHS OF OBJECTS IN MOTION

A photographic dark room was established as a regular adjunct of the draughting office of William Sellers & Co., and special cameras and apparatus were devised, the apprentices taking turns in printing, developing, and mounting the photographs. His success in this special application of photography to his business led him to try portrait and landscape work in his hours of relaxation, and for years this proved his most absorbing hobby. In its pursuit he invented several useful aids for the photographer, patented a cheap and effective rolling press for mounting prints, and made various ingenious portable dark chambers or "tents" for field work with the "wet" process.

Washing negatives after development and before "fixing" was one of the difficulties of field work at that time, as it was not always easy to procure the necessary supply of water, and to carry it about added a considerable weight to the apparatus; but Dr. Sellers discovered that washing might be deferred to a more convenient season if the plate be coated with a mixture of glycerine and water and then shut up in a tight box. This enabled him to preserve "unfixed" plates for months, and greatly simplified the practice of field photography by the wet process, which has long since, however, given way to the "dry" plate.

During 1861 and 1862 he acted as American correspondent for the *British Journal of Photography*, and was for many years a frequent contributor to American photographic publications. He was one of the founders of the Philadelphia Photographic Society, as well as a prominent member of the Amateur Exchange Club, an active organisation founded in 1861 by Mr. H. T. Anthony, of New York, which included in its membership a number of bright men in various walks of life.*

In 1861 Dr. Sellers made and pat-

* Dr. Oliver Wendell Holmes was a member or at least a correspondent of the club, and it was in reference to some personal photographs sent to him by Dr. Coleman Sellers, whom he had not then met, that he wrote in "Doings of the Sunbeam" as follows:

"The artist sends his own presentiment, not the stiff shape of a purchased carte de visite, but as seen in his study or parlor, surrounded by the domestic accidents which so add to the individuality of the student or artist. You see him at his desk or table with his books and stereoscopes about him; you notice the lamp by which he reads, the objects lying about; you guess his condition, whether married or single; you divine his tastes apart from that which he has in common with yourself. By and by, and as he warms toward you, he sends you the picture of what lies next to his heart, a lovely boy for instance, such as now laughs upon us in the delicious portrait on which we are now looking, or an old homestead, fragrant with all the roses of its dead summers, caught in one of nature's loving moments, with the sunshine gilding it like the light of his memory. And so these shadows have made him, with his outer and his inner life, a reality to you, and but for his voice, which you have never heard, you know him better than hundreds who call him by name as they meet him year after year and reckon him among their familiar acquaintances."

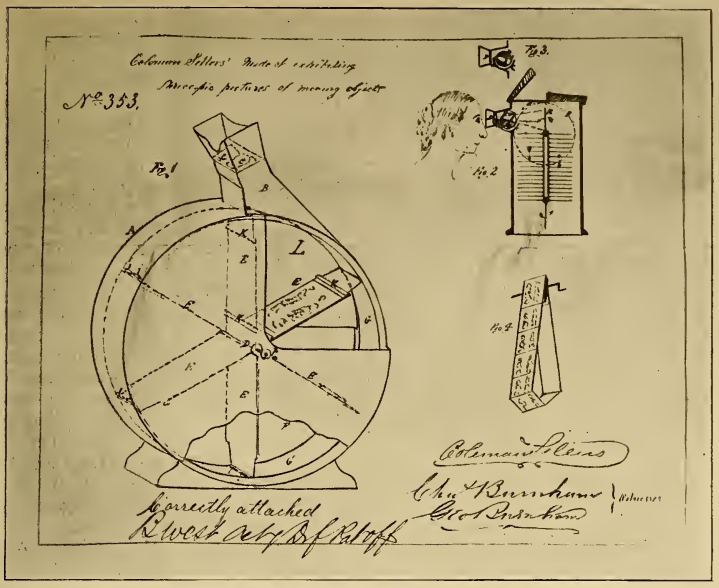


FIG. 4.—A REPRODUCTION OF DR. SELLERS' PATENT DRAWING OF HIS KINEMATOSCOPE OF 1861

ented a device which he called the kinematoscope (see Fig. 3) for the exhibition of stereoscopic pictures of objects in motion, which, in point of fact, was the crude prototype of the modern machines for displaying moving objects, such as the biograph, kinetoscope, and others. The machine accomplished the object intended in a practical manner, but required for its full development instantaneous photography, which had not at that time been invented. As will be seen by reference to the illustration, the stereoscopic prints were mounted radially around a horizontal axis, so that rotation brought them successively before the lenses. The operation to be reproduced was divided into a suitable number of parts, the subject being posed for each part of the movement. As many seconds were required for each pose with the slow plates then used, great care was necessary on the part of the operator and model to get perfect registration of the successive views. The result, however, was quite successful in portraying such simple, repeated movements, as of a boy driving a nail or a lady sewing.

The form of the device shown in Fig. 3 was its simplest shape; but Dr. Sellers also contemplated the use of an endless belt approximating more closely the modern highly developed machine, as will be seen by reference to Fig. 4, which is a reproduction of his patent drawing. As illustrating the scientific method with which Dr. Sellers usually works out his inventions, it is interesting to quote from his patent application the following:—

"What I aim to accomplish is, to so exhibit stereoscopic pictures as to make them represent objects in motion, such as the revolving wheels of machinery and various motions of the human body, adding to the wonders of that marvellous invention, 'The Stereoscope,' a semblance to life that can come only from motion. It is to breathe into the statue-

like forms of the stereograph, as it were, the breath of life. * * * It must be done by viewing in succession a series of pictures (taken in different positions of the moving object) with sufficient rapidity to insure the image of one being retained on the retina until the next one is brought into view. This has frequently been done with plain pictures, but has never been done with them in the usual manner of exhibiting such pictures. In the phantasmascope, as it is usually constructed, the pictures are arranged in a circle on a cardboard, and are viewed through holes corresponding in number to the pictures. In these toys the pictures pass before the eye, and are seen for a greater or less time, according to the size of the holes, and it has been found that, unless the holes are very small, a blurring effect is produced.

"On this plan my first instruments were designed; that is, I arranged a series of stereoscopic pictures around a cylinder and made use of various cut-off devices to produce the instantaneous vision required; but in all cases, though I found the appearance of motion was produced, yet there was a blurring of the image that prevented my seeing the fine detail of the pictures. After a long series of experiments, I made the discovery that it is absolutely necessary that the pictures should be entirely at rest during the moment of vision, or that motion should be in a direction of the line of vision, that is, advancing towards the eye or receding from it, just as you would take a card in both hands and move it rapidly to and from you, in contradistinction to moving it from right to left or up and down."

From those early days of the art until the present time Dr. Sellers has kept in touch with the developments in photography, and has always had in his residence a well-equipped dark-room. About 1873 he delivered before the Franklin Institute three lectures on photography, in one of which he introduced the experiment of taking a photograph by artificial light and developing the negative in the field of a projecting lantern, thus enabling the audience to follow in the screen the entire process, including washing and fixing. He also demonstrated, in an interesting manner, the actinic power of the invisible spectrum beyond the violet rays.

Photography, which became with him an absorbing pastime, was taken up in its direct application to his engineering work, and the same object has frequently led to his interest in other pursuits which have afforded outlets for his tireless energy. Thus it once occurred to him that valuable information might be obtained by a careful microscopic study of the stony deposit or scale, which forms in steam boilers when certain waters are used, and, entering into the investigation with his usual zeal, he prepared a number of interesting specimens by mounting sections which he ground to a transparent thinness for study with polarised light. He familiarised himself in this way with the methods of mounting microscopic specimens both wet and dry, and prepared a number of excellent slides, incidentally devoting particular attention to the diatomaceous earths and fresh-water algæ. He also contrived a number of handy appliances for use in connection with this work, and later, as a matter of amusement, applied the microscope to lantern work, providing himself with an oxy-hydrogen outfit, and making his own oxygen, as this gas was not then an article of commerce.

In his more recent professional career, as in the earlier period referred to, where questions arise that suggest original investigation, it is still his habit to devote to such study and research those hours one usually gives to rest and recreation. When, for instance, the great tunnel of the Niagara Falls Power Company was under construction, it became necessary to determine what lining material would best resist the abrasive action of the flowing water. As information at hand was very meagre, it occurred to Dr. Sellers that an application of the sand blast might be made to show the relative hardness of the several materials under consideration. Therefore, during spare moments he fitted up at his residence an apparatus by which a definite

quantity of sand could be forced at a given pressure against the substances to be tested, and in this way he determined and tabulated the relative abrasion of brick, concrete, cement, etc., measured by the loss of weight due to the blast on the test specimen.

One could cite many similar instances in connection with his work at Niagara Falls in which, by such personal research, requiring frequently the making of ingenious working models or apparatus, Dr. Sellers has determined many important questions, in both engineering and physics, to the advantage of the undertaking.

As the result of personal observation extending over many years and facilitated by the most intimate acquaintance, the writer does not hesitate to say that Dr. Sellers furnishes a most striking illustration of intellectual power unconfined by the limitations of any single subject or class of subjects, but reaching out into countless directions. In great things or little, to whatever subject he turns his attention, he masters it with astonishing rapidity and completeness.

I remember, for example, quite early in my acquaintance with him, he took up the art of telegraphic signalling as a convenience in communicating between the several departments in the extensive establishment of William Sellers & Co., and in the course of a few months he made himself an expert operator, not only signalling, but reading messages by ear, though the average time for the acquisition of this skill is about two years. It was the same with shorthand, in which, becoming interested, he persisted until he acquired considerable skill, although his opportunities for practice were only the occasional leisure moments of a very busy life.

In his early manhood he amused himself and others at odd moments with feats of sleight-of-hand, in which he was quite as expert as many professional prestidigitators. Besides the entertainment of informal gatherings of friends, he turned this accomplishment to account during the Civil War by giving performances at the hospitals for the amusement of the wounded soldiers, for elsewhere for the benefit of the Sanitary Commission, in which he was actively interested. While the proficiency he attained in this direction was chiefly a source of amusement to himself and others, it is a highly characteristic instance of mental concentration.

It was applied most effectively when serving as a member of the commission appointed by the University of Pennsylvania in accordance with the bequest of the late Henry Seybert to investigate the phenomena of modern spiritualism. These researches were begun in 1884, and continued for three years, during which time Dr. Sellers' special training was of great value to his fellow commissioners in devising tests and suggesting methods of investigation and observation. His strong common sense, his thorough knowledge of natural laws, have predisposed him at all times to challenge those who claim occult powers, and have enabled him to detect the impostures of charlatans. While he is entirely untrammeled by prejudice and his mind is ever open to the reception of new truths, he will never resort to hypothetical new "forces" to explain alleged phenomena until he has exhausted the possibilities of those forces of Nature which are already recognised.

It is characteristic of Dr. Sellers that throughout his life he has ever been ready to impart his knowledge to others, and he excels in the happy faculty of placing a subject clearly before the learner without emphasising the latter's want of knowledge. He has always sympathised with organisations for experimental investigation in physics and mechanics, and as a mere youth in Cincinnati he attached himself to the "Mechanics Institute" of that city, whose meetings he attended and in whose hall he gave his first lectures.

Soon after his return to Philadelphia he took up, with earnest zeal, the work of the now venerable Franklin Institute, serving on numerous important investigating committees, and contributing largely to the interest of the meetings by timely papers, discussions, and lectures. He served as vice-president for several years, and was elected president

for five successive terms. He is still one of the board of managers, his service in this capacity having now extended over a long period, and he is also one of the publication committee that edits the Institute's *Journal*. He has taken an active part in organising and managing the public exhibitions held from time to time under the auspices of the Institute, notably that of 1874.

When the writer was secretary of the Institute, a series of scientific lectures was projected by the managers. These lectures were to be delivered by the secretary, and were to be illustrated with brilliant experiments, produced on an unprecedented scale of magnitude. The lectures took place in 1865 and the six succeeding years, in the Academy of Music, before audiences of 3000 persons. Dr. Sellers took an active and most useful part in the work of preparation, and acted as stage manager in charge of the large corps of assistants required to manipulate apparatus for experiments that were then performed on a scale never before attempted; and it is largely due to his energy, ingenuity, and resourcefulness that the lectures proved so successful.

He was a charter member, and is a past president of the American Society of Mechanical Engineers, and for their meeting of 1880 wrote his often quoted paper entitled, "The Metric System: Is it Wise to Introduce it Into our Machine Shops?" His well-known antagonism to all attempts to enforce the use of the metric system by legislative enactment has induced him to write freely on the subject in the technical and newspaper press, and he also prepared, in connection with the late Dr. William P. Tatham, the adverse report which was adopted by the Franklin Institute in 1876.

Among other societies to which Dr. Sellers belongs may be mentioned the American Society of Civil Engineers, the Society of Naval Architects and Marine Engineers, the British Institution of Civil Engineers, and the British Institution of Mechanical Engineers, the Geneva Society of Arts, the Pennsylvania Historical Society, and the venerable American Philosophical Society, founded by Benjamin Franklin. His membership in the great British engineering societies was, without solicitation, tendered him in 1884 on the nomination of a number of the most eminent men of science in England. During the Centennial Exhibition in 1876 he served as one of the special judges for final settlement of difficult or disputed questions of award. For his well-known scientific attainments he was decorated by King Oscar of Norway and Sweden with the order of St. Olaf, and in 1899 the University of Pennsylvania conferred on him the honorary degree of Doctor of Science.

Dr. Sellers paid his first visit to Europe in 1884, when, as professor of mechanics and member of the board of managers of the Franklin Institute, he acted as delegate from that society to the ter-centenary of the University of Edinburgh. During a stay of several months in England he visited the large works of Sir William Armstrong and Sir Joseph Whitworth under the most favourable auspices, finding open to him also the doors of any establishment he wished to see, even those that were noted as being generally closed to all the world. In many of these he found some of his own inventions, and that designs made by him as engineer for William Sellers & Co. had been copied and were in use. His trip was extended through France, Germany, Sweden, and Norway, in which last-mentioned countries he met with a particularly hearty welcome.

In 1886 he again crossed the ocean, spending the summer in the Scottish Highlands, and upon his return to America ill health obliged him to give up his former duties. He, therefore, resigned his position as engineer of William Sellers & Co., Inc., and subsequently took up active practice as a consulting engineer, for which he had been prepared by an experience of more than forty years as designer and manufacturer.

When it became known that he had entered upon this independent professional work the writer, as president of

Stevens Institute of Technology, at Hoboken, New Jersey, immediately urged that he should lecture before the senior class of that institution. This resulted in the establishment of a Chair of Engineering Practice, with Dr. Sellers as a non-resident member of the faculty. This chair was founded with the intention of giving the students a better knowledge of the use to which they could apply in actual practice the technical knowledge they were obtaining, and further, to bring them into close touch with the customs and requirements of practical engineering. The lectures delivered at Stevens during a number of years were attended not only by the senior class, but also by members of the faculty, who received from Dr. Sellers' extended experience many hints to aid them in their instruction. In 1887 he received from Stevens Institute the honorary degree of Doctor of Engineering.

In 1889 Dr. Sellers was requested by Mr. Edward D. Adams, the well-known financier, of New York, to report on the practicability of generating electricity by water-power, and the electric transmission of power from Niagara Falls to Buffalo. This was in the interest of what afterward developed into the Niagara Falls Power Company. The proposed utilisation of the power of Niagara Falls was based upon a scheme that had been suggested by Thomas Evershed, an engineer upon the Erie Canal, who had conceived the idea of placing turbine wheels in a district more than a mile above the falls, discharging into an outlet tunnel that should inconspicuously debouch at the river edge below the falls. Legislation had been obtained upon this scheme from the State of New York, though capitalists were not immediately ready to believe that the project would be commercially profitable. Dr. Sellers' report, however, so strongly endorsed the practicability of the scheme that capitalists were readily found who were willing to undertake the enterprise.

He was made consulting engineer of the Cataract Construction Company, a corporation formed to execute the work, and, in June of 1890, assisted in the establishment in London of the International Niagara Commission, with power to award $22,000 in prizes for plans for generation of power by water and its transmission to a distance by the most economic method, regardless of the medium of transmission. This commission consisted of Sir William Thompson (now Lord Kelvin) as chairman, with Dr. Coleman Sellers, Lieutenant-Colonel Theodore Turrettini, of Geneva, Switzerland (originator and engineer of the great water-power installation on the Rhone), and Prof. E. Mascart, of the College of France, as members, and with Prof. William Cawthorne Unwin, Dean of the Central Institute of the Guilds of the City of London, as secretary.

At that time great advances had been made in the transmission of power by wire rope and by compressed air; but very little had been done in the utilisation of electricity for power purposes. Inquiries and examination into the best methods of developing and transmitting power then known in England, France, Switzerland, and Italy were made personally by the officers and engineers of the company, and competitive plans were received from twenty carefully selected engineers, designers, manufacturers, and users of power in Great Britain, on the Continent of Europe and in America. All of these plans were submitted to the commission in London on or before January 1, 1891, and prizes were awarded for such of the plans as were considered favourably by the commission.

The engineers who were engaged to carry out the plans of the company were organised into a board of which Dr. Sellers was made chairman. The work was begun on the construction of the tunnel, and also on the entrance canal by which the water was to be brought to the turbines. In 1893, when the tunnel was nearly completed and the time for the installation of the machinery was near at hand, the object of the Board of Engineers had been accomplished, and it was dissolved. It then became pre-eminently the task of the mechani-

cal engineer to consider and apply the devices best adapted to so control and utilise the forces as to secure the best engineering and commercial results. Dr. Sellers was accordingly made chief engineer of the Cataract Construction Company, and while its separate organisation was called for, he served also as president of the Niagara Falls Power Company. It thus devolved upon him to suggest and devise the various details of the installation at a time when its principal features were essentially experimental, and it is needless to say how successful has been the outcome of the conservative course pursued by him throughout his active connection with this work.

Radical changes in the plans were necessary when it became evident that the proper course lay in the abandonment of Mr. Evershed's scheme of a system of distributing canals leading to factory sites where independent water-wheels would be installed, and to substitute in place thereof a central power station where the generation of 50,000 H. P. would be concentrated for electric transmission to consumers located on the neighbouring lands or at a distance. The first three turbines were put in operation in 1895 with a sufficient demand for power in excess of their output to warrant the installation of five additional units, which were shortly followed by two more, making in all an equipment of 50,000 H. P. capacity.

A second power house, located on the opposite side of the entrance canal, is now under construction to accommodate eleven 5000 H. P. units of improved design, and this, when completed, will bring the total capacity of the plant on the American side of the falls to over 100,000 H. P.

Dr. Sellers' foresight and judgment in advising the methods to be adoped at a time when the problems were without precedent, and the mechanical features invented by him in designing the large dynamos and their appurtenances, have largely contributed to the success of this initial installation, and certainly greatly simplify the further extension of the plant now in contemplation. The work has thus far extended over a period of twelve years, and, so far as Dr. Sellers' part in it is concerned, it may be justly considered as the crowning achievement of a life devoted to engineering practice.

Current Topics

THE radio-active metals, radium, uranium, and others, continue to receive marked attention from scientists and the public alike. The phenomenon that is, perhaps, the most interesting in connection with these elements is that in which they appear to emit rays of energy perpetually without apparent means of restoration. Thus it has been estimated that the loss by radiation from uranium or thorium would be about one milligram in one million years, while in the case of radium it has been estimated that the same change would take place in about one year, from which it has been deduced that the life of any radium that now exists is about 1000 years. Following this comes the startling suggestion from Sir William Crookes, in the course of an address before the recent International Chemical Congress at Berlin, that it is conceivably justifiable to doubt the permanent stability of matter. "The chemical atom," he said, "may be actually suffering a catabolic transformation, but at so slow a rate that, supposing a million atoms to fly off every second, it would take a century for its weight to diminish by one milligram. This fatal quality of atomic dissociation appears to be universal and operates whenever we brush a piece of glass with silk. It works in the sunshine and raindrops, in the lightning and flame. It prevails in the waterfall and stormy sea, and although the whole range of human experience is all too short to afford a parallax by which the extinction of all matter can be calculated, 'protyle,' the 'formless mist,' may once again reign supreme and the hour-hand of eternity will have completed one revolution." It may be interesting in this relation to note that Professor Crookes predicted the possibility of wireless telegraphy by ether waves as we now know it some years before the advent of Marconi.

A GERMAN physicist recently came forward with a statement that experiments which he had made appeared to contradict these views, and that there was a marked loss in weight of the material within a comparatively short period. This statement was scarcely made, however, before the experimenter hastened to recall his paper on the subject, with the explanation that he had discovered a defect in his apparatus which had given him erroneous results. Numerous attempts have been made to explain the phenomenon in question. Thus, Sir William Crookes offered an explanation, which was published in these columns last September, to the effect that radium possesses the property

of drawing energy from quick-moving molecules of the atmosphere smashing onto its surface, while the slow-moving molecules are thrown off. The reduction of the speed of the quick-moving molecules cools the layer of air to which they belong, but this cooling is rapidly compensated by radiation and conduction from the surrounding atmosphere, with the result that the difference in temperature is scarcely perceptible, and hence the phenomena referred to. Dr. J. J. Thomson, however, in a recent article in *Nature*, has pointed out that the energy of radium cannot be drawn from the air in this way, inasmuch as when, for instance, a piece of radium is enclosed in a block of ice, it continues to radiate heat sufficient to melt its own weight of ice in two hours, although this heat cannot be drawn from the external air, since the melted ice around the cavity is hotter than the ice surrounding it. Dr. Thomson then offers the explanation that possibly this phenomenon of heat radiation without apparent loss is to be found in the enormous intrinsic energy contained in the atoms of radium, which, according to his calculations, is sufficient to maintain the radiation for 30,000 years at the rate observed by Curie, in which it was assumed that each atom lost but one per cent. of its total energy.

Amongst other recent announcements concerning these remarkable substances, Messrs. E. Rutherford and F. Soddy state that they have, as a result of numerous experiments, made the interesting discovery that the radio-active emanation from these elements is a vapour possessing definite points of condensation and vaporisation; and M. G. Bohn has discovered that while the radiations in question have a destructive effect upon animal tissues, they appear to have a stimulating effect upon organisms,—such as the larvæ of frogs and toads, which effect is either positive or negative according to age and species. M. Bohn discovered that when the larvæ is exposed at an early age for a few hours to the radium emanations an abnormal development is produced at a later age, which development singularly remains latent in the interval.

Speaking of the development of water-powers in his presidential address a short time ago before the Institution of Civil Engineers, Mr. John Clarke Hawkshaw gave a brief, but interesting, survey of some of the more important accomplishments in this branch of engineering in different parts of the world and of the possibilities yet to be realised. The great difficulty in the way of utilising falls of water for industrial purposes is the variation in the supply of water, which, in all water courses, depends upon the seasons. In some cases, as Mr. Hawkshaw remarked, the supply falls off in winter when the sources are frozen, and is abundant in summer when glaciers and snow melt. In others the reverse is the case, and the falling off is during the summer droughts. Even Niagara, notwithstanding the regulating effect of the Great Lakes, is subject to considerable variation. But where, as at Niagara, the available power is so much in excess of requirements, this variation is of little moment if we consider only the supply of water for power; and yet an artificial regulation of the lakes is under consideration, with a view to prevent too great a variation in the level of the surface owing to the discharge through canals for power and other purposes. In smaller rivers it is necessary to consider the minimum flow, and if that falls very low, or is subject to much variation from year to year, the uncertainty may make the source of power of little value.

The only remedy against this variation is to regulate the flow of water in the river by building dams and storing the flood-water at suitable places. In a settled country this will generally be a matter of great difficulty, and often of prohibitive cost, owing to the interference with vested interests which any

variation of the accustomed levels of the water will bring about. The cost is reduced to a minimum when lakes can be used for storage reservoirs. At Foyers, the one example of water-power used for industrial purposes on a considerable scale in Great Britain, sufficient water could be obtained only by lake-storage. In Ireland, the Shannon is a river well adapted for providing water-power. It has a rapid fall near the sea, and large lakes conveniently placed for storage reservoirs; but fisheries, navigation and the vested rights of riparian owners have, so far, barred the way to the full use of the large power available there. In countries where the land is uncultivated and of little value, as in parts of South Africa, and where the rivers are dry or of small volume at certain seasons of the year, it will often be possible to form large reservoirs in the river valley itself, at a comparatively small cost; but, as a rule, this will exceed the cost of storing water in existing lakes.

In Norway the greatest facilities exist for regulating the rivers, and thereby obtaining a large measure of the power to be derived from the water flowing into them. Lakes, many of large size, may be numbered by thousands. Many of these have already been regulated, some for navigation purposes and some for timber-floating, and some are now being regulated for water-power. On Lake Mjösen storage has been provided for 840,000,000 cubic metres, at a cost of £14,400. It is estimated that 263,000 H. P. could be supplied by the larger rivers of Norway south of Trondhjem without regulation; by regulation the power would probably be quadrupled. At one of the falls on the Glommen, where there is 45,000 H. P. available, a power house is now being erected from which the power will be transmitted to Christiania. Germany, Austria, and Switzerland have made larger use of water-power for industrial purposes, and in some cases for working railways. France uses water-power to the extent of 500,000 H. P. already. Italy is making use of her waterfalls, transmitting power to a distance of sixty-two miles on Lake Como for railway and other purposes.

It is in the United States, however, that most progress is being made in the electrical transmission of water-power. Forty-three companies, having a total capacity of 177,300 H. P., transmit power over a line distance of 1549 miles, on an average 36 miles, with a voltage which ranges from 10,000 to 60,000 volts. The maximum distance over which power is transmitted is from Colgate to San Francisco, 220 miles, with a loss of 25 per cent. Waterfalls are made use of under the most varied conditions as regards volume and fall. At Niagara the body of water is large, and the fall is between 150 and 200 feet; at Sault Ste. Marie, between Lakes Superior and Huron, the body of water is also large, but the fall is small, namely, 24 feet; at Colgate the body of water is small, but the fall is 1500 feet.

Russia in Europe has not available water-power at all in proportion to its area. An Imperial Commission recently decided that the water-power on the navigable rivers belongs to the government, and its utilisation will depend on how far they deal with it in a liberal spirit. The hot, dry summers and cold winters are not favourable to water-power; and it is believed in Russia that the increasing destruction of forests is prejudicially affecting the rivers, which have too much water in spring and too little in summer. Several important projects are, however, under consideration. One is to develop 100,000 H. P. on the River Mista to work the St. Petersburg & Moscow Railway. Another is on the Volkhov River, which connects the Ilmen and Ladoga lakes. At the falls of the River Narova, at Narva, it is estimated that 40,000 H. P. can be obtained, of which 15,000 H. P. is already used. In Finland there are the Great and Little Imatra Falls, also Prince Menchikoff's Rapids, near

Kotka, with 40,000 H. P., of which 15,000 H. P. is already utilised.

In South America, where coal is wanting, the rivers which flow down the western slopes of the Andes will form a fruitful source of power. In Argentina a beginning has already been made at Cordova. Many of the rivers from the Andes are now absorbed in the arid deserts of the western pampas, and their regulation will serve the double purpose of irrigation and power. Brazil has one grand fall, that of Paulo Alfonso, 147 miles from the sea on the Rio San Francisco, which is navigable to the fall. By some who have seen both, this fall is regarded as a finer sight than Niagara. Africa, with its four great rivers and notable waterfalls, has a vast amount of water-power in store for the future. Notwithstanding the requirements for irrigation, some water should be available for power at Assouan, on the Nile. Above the first cataract are six more, and farther south are the Murchison Falls, where the Nile descends 700 feet in 10 to 15 miles. On the Zambesi there is the Victoria fall, which will soon be accessible by rail. Its height is more than two and a half times that of Niagara. At Stanley Pool, on the Congo, Stanley estimates the discharge when the river is lowest at 1,436,850 cubic feet per second, more than four times the maximum discharge at Niagara. In Southern India a beginning has been made. Electric power is supplied to the Kolar gold fields from the Cauvery Falls, distant ninety miles; and it is estimated that 60,000 H. P. can be obtained from the Periyar reservoir, which was made for irrigation purposes. There are other sources available for water-power in Northern India, some of which have already been considered with a view to their utilisation. In course of time these great waterfalls of the world will all become centres of industry and manufacture.

With the advent of mid-summer temperatures, the cooling of buildings becomes a refreshing subject for consideration. The more one inquires into it, however, the more one wonders why buildings are not more generally cooled by such means as are readily available. It cannot be altogether that cost of operation is a controlling factor, for, to begin with, it would not be a serious item; and then, too, since much money is freely expended in equipping buildings with heating systems and in operating these in cold weather, assuredly a fair expense ought to be cheerfully assumed to secure a somewhat corresponding degree of comfort during the heated term. An indirect steam or hot-water heating system would lend itself well to a reversal of functions and would be comparatively simple and cheap to operate. A fan or blower would be necessary to drive air over the coils underneath the lower floor and into the rooms through the usual ducts and registers; and the supply pipes for the coils would have to be connected with a water cooler or other means of refrigeration, with a pump interposed for circulating the cooling agent through the system. Essentially there is nothing complicated or expensive about the outfit, and the comforts which it promises are alluring.

In a recent issue of *Ice and Refrigeration* Mr. Alfred Siebert goes into some detail concerning the cooling of dwellings on this plan, telling, among other things, that it is not advisable to use brine or ammonia direct in the coils for cooling the air. Brine will corrode the pipes and ammonia may leak and cause smell in the rooms. Furthermore, brine or gas might have a temperature below the freezing point, in which event condensation will form on pipes and coils, with consequent dripping and possible freezing, which would reduce the cooling capacity of the pipes. The cooling medium, according to Mr. Siebert, should never be below 65 or 70 degrees F., preferably 70. In that case the air will not be too moist, it being cooled so little; otherwise the cooling effect would be partly counteracted by the increased

humidity, which is always oppressive. If lower temperatures are required and a low humidity besides, the air must be cooled to a much lower temperature than actually required and then heated to the proper temperature in order to remove the excessive moisture; or the air must be dried by passing it over chloride of calcium. Cool water makes an excellent circulating medium for the coils.

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It is considered good practice to renew the air in living rooms four times every hour, and, therefore, the requisite amount of cooled air must be furnished and an equivalent outlet for the warm or impure air be provided. It must further be understood that, in order to keep a room cool, doors and windows must be tight and must be opened as little and as seldom as possible; every opening will make warm air rush in. The cool air should be brought in near the floor line, while the outlets for the warm air should be close to the ceiling. Having the cooling pipes directly in the room is not a good plan, and, hence, a house equipped with a heating system of direct radiators would not lend itself so well to cooling. It would be coolest near such radiators, enough so, possibly, to be unpleasant, while it would be warm in the middle of the room owing to lack of air circulation. Condensation of moisture on the radiators would also prove a troublesome factor. But for the house with an indirect heating system, the cooling problem is a relatively simple one and an attractive one.

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It may not be uninteresting to add here, as in a measure related to the subject of refrigeration, that liquid air is now being delivered in Berlin, two liters, or, roughly, half a gallon, at a time for about thirty-five cents. In a recent issue of *Energie*, of that city, it is stated that the receptacles are made of glass, with double walls, the space between the walls being filled with an insulating material, the walls being silvered to prevent the radiation of heat, and the whole enveloped in an insulating material. They retain their temperature for fourteen days. Several drops of the liquid in a glass of water produce freezing, and it is intended for such uses as refreshing drinks and improving the condition of the air in sick rooms.

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One of the unsolved problems in engineering of which Mr. W. H. Maw spoke in a recent lecture before the Institution of Civil Engineers was that of the steam jacket for steam engines. In a lecture on "The Development of the Experimental Study of Heat-Engines," delivered by Professor Unwin in 1895, an excellent account was given of the growth of the accepted theories as to the action of steam in an engine, and of the important effect of cylinder condensation on economical working. But Professor Unwin, according to Mr. Maw, was careful to point out that, whereas on theoretical considerations alone, the use of steam jackets might always be expected to afford highly beneficial results, yet in practice the economy obtained by steam jacketing varied greatly, and was in some cases a negligible quantity. The causes for this are, to a great extent, known in general terms. For instance, we know that the beneficial effect of jackets increases with an increase in the proportion of the area of the jacketed surface to the quantity of steam passing through the cylinder in a given unit of time, and also that it is apparently affected by the character of the jacketed surfaces. But when we come to quantitative results, we find that our knowledge is far from being of that exact and definite kind which is of real scientific value. And this state of things is reflected in the current practice of leading steam engine builders. There are, of course, cases in which the question of jackets or no jackets is settled by considerations of cost or of weights, without regard to economy; but, putting those cases aside, we find a divergence in practice which it is impossible to reconcile with

the possession of adequate experimental data. Thus we shall find, say, triple-expansion engines of practically the same size, and designed for the same steam pressures and piston speeds, and working under the same conditions, but constructed by different makers, provided with jackets to all cylinders and covers, with jackets to the barrels of cylinders only, with a jacket on the high-pressure cylinder only, or on the low-pressure cylinder only; with steam at full pressure admitted to all jackets, or with provision for varying the steam pressure in the different jackets; and for all these variations in practice the designers will, as a rule, be prepared to quote reasons which they regard as adequate. The only satisfactory explanation of this condition of things would be that the differences in economy consequent upon the adoption of the variations in practice are so small as to be masked by the differences which necessarily occur in engine management; but, if this explanation were the true one, it would be an exceedingly strong argument for the entire abandonment of jackets in the class of engines under consideration, and for securing the consequent saving in the cost of construction which the omission of such jackets would effect. This explanation, however, is not a satisfactory one, and, in view of the great interests,—monetary and otherwise,—involved, the whole question of steam jacketing, and particularly the application of such jackets to compound or multi-expansion engines of modern types and of large power, using steam at high pressures, deserves a much more thorough and systematic investigation than it has hitherto received.

It may appear strange that at the present stage of the history of the steam engine, and in view of the enormous number of experiments on such engines which have been carried out during the past half century, any such question as this should remain unsettled. But it must be remembered that not only are many of these so-called experiments wanting in scientific accuracy, but also that even those of the better class are often either incompletely recorded, or are,—from the various characters of the engines on which they were made,—very difficult to compare. There has also to be borne in mind the great increase in the size of engines and in steam pressures which has occurred during the past few years,—increases which render earlier experiments inapplicable to present-day practice. And here it may be well to point out that there is a great difference between a strictly systematic investigation, such as Mr. Maw has in view, and an ordinary engine trial. Thus, to ascertain why, in a given instance, certain pressures of steam in the jackets of a compound engine have given the best results, we must have full information as to the condition of the steam in each cylinder of that engine throughout the stroke. We must know its pressure, temperature, and the amount of moisture it contains at admission, at the point of cut-off, and at exhaust; and we must be able to trace how far alterations in its condition are due to heat received from the jacket or to other causes. We must, in fact, if we desire to properly investigate the merits and demerits of steam jacketing under various conditions, not be content with ascertaining that in a particular set of instances the use or disuse of a jacket effected, or did not effect, economy; but we must trace out the reasons for such results, and be able to account satisfactorily for the disposal of all heat supplied to the engine.

One other of the several problems mentioned by Mr. Maw is the determination of what the change really is which we call elastic fatigue of metals. The indications of ordinary testing machines do not reveal any change in the behaviour of a material which has certainly exhausted a large proportion of its "life" under repeated applications of stress, and we must evidently, to solve the problem, have recourse to other

modes of inquiry. What is the change of structure produced by fatigue, and in the case of any but pure metals is this change accompanied by any rearrangement of the constituents? How is this change of structure affected by variations of treatments, by annealing, or, in the case of steel, by tempering? Half a century ago we might have been inclined to answer these questions in an off-hand way, but we have now a better knowledge of the possibilities of change in the structure of a solid metal, particularly an alloy, and we have learned that an extension of that knowledge promises to open up the most certain road to securing for our use constructive materials possessing qualities far in advance of those now available. It is to the efficient employment of the microscope that we must look for our chief aid in determining the changes which the structure of a metal undergoes as the result of the application of repeated loads; and there are two points in connection with the use of this system of investigation which merit special attention. The first of these is the information which microscopic examination may be expected to afford as to the influence of the shape of specimens on the effect of repeated stresses. In the case of repeated applications of plain tensile strains the results may possibly be fairly uniform over the whole section of the specimen; but in the case of cross-bending or torsional stresses, the result must be far otherwise, and microscopic examination of samples taken from various parts of the cross-section may be expected to afford most interesting information as to the manner in which the growth of failure,—as it may be called,—proceeds.

THE second point, mentioned above, is to some extent dependent upon the first, and it is this: --Cases not infrequently arise in which it is of considerable importance to ascertain whether a certain object, as, for instance, a propeller shaft, or a portion of a bridge structure, or a steel rail, has or has not been injured by the repeated applications of stress to which it has been subjected; and at present the only method of determining this is the testing to destruction of the object respecting which the information is desired. But if we know accurately in what part of the object the stresses to which it had been subjected would first cause injury, and if we further knew in what way the existence of such injury would be indicated by change of structure, it would follow that the microscopic examination of a small portion, cut from the most sensitive part of the object, would afford a valuable indication of what was going on. A few years ago it would have been regarded as utterly chimerical to propose such a method of examination as this; but we are rapidly learning to appreciate the lessons which the microscope can teach us, and the problem of what may be termed the "microscopic analysis of fatigue" is one which cannot be regarded as being beyond our powers to solve.

THE man with the monkey wrench has always been held accountable for many of the troubles with machinery, and at the time of the first appearance of the enclosed types of engines of the smaller sizes one of the points of advantage claimed for them was that the moving parts were proof against "tinkering" by unskilled attendants. But the man with the wrench may work damage in other places as well. In a paper read at the recent meeting of the American Society of Mechanical Engineers, Mr. A. Bement, for example, directed attention to the fact that with the prevailing practice and methods of erecting machinery in final place there is ample opportunity for damage from excessive tightening of nuts and screws on the part of the erecting crews, leading to straining of parts beyond their elastic limit. There appears to be no rule in general use for the guidance of the men who perform the work of machinery erection, and it seems usually to be their desire to make things as tight as possible. The natural result is that elastic limits are often exceeded or that

breakages even may occur. As an illustration of this Mr. Bement showed a diagram of one end of a vertical Corliss engine cylinder in which the nuts of the studs holding the head to the flange were screwed up so tight that it resulted in over-strain, finding relief in a crack, which developed in the wall of the cylinder just under the flange. A tongue on the head fitted into a groove in the face of the cylinder flange; packing for making the joint was compressed in the groove by the pressure exerted by the tongue; when the packing was fully compressed, further strain owing to over-tightening of the bolts resulted in the fracture which manifested itself some weeks after the joint had been made up. The crack extended part way around the cylinder, but did not result in entire rupture. It appears that when sufficient relief had been secured, the crack ceased to extend, notwithstanding the presence of the steam pressure. This case is probably fairly illustrative of many others of which nothing is heard.

SOME recent experiments in Germany by Professor R. Stribeck, on the changes produced in the physical properties of copper by the combined effects of high temperature and continued strain, throw new light on the subject of copper steam pipe failures which, in recent years, have attracted so much attention. While it is known that above a certain temperature the strength of copper decreases rapidly, the experiments mentioned are novel in that they introduce the time factor. It was found that this played a very important part. Thus, while even at 500° F. a test piece broken rapidly showed no perceptible lowering of the yield point and of the ultimate strength of the material, a much smaller strain applied for a number of hours was sufficient to break the piece at a temperature as low as 390° F.; and the longer the time of application of the strain, within limits, the less the critical temperature seems to be. In other words, heat does not seriously affect the ultimate strength of copper, but it causes this metal to fatigue more rapidly. In all cases a very marked decrease in the reduction of area was noticeable, showing that high temperatures seriously affect the ductility of copper. These characteristics have a rather important bearing on the design of steam piping, for as all calculations are based on the results of tests made on the cold metal, which do not correctly represent the properties of the metal when hot, piping which is designed to have a certain factor of safety is actually very much nearer the danger point than is supposed; and the longer it is in use, the nearer it comes to that point. Where only ordinary pressures, and hence low temperatures, are used, and where the original factor of safety is high, so that the working load does not approach the calculated safe limit very closely, there is not much to fear. But if copper is used to carry high-pressure steam, and especially if used with superheated steam, both ductility and strength of the metal are much decreased. These conclusions may clear up some of the cases of copper steam pipe failure for which no entirely satisfactory reason could, so far, be assigned.

FROM a recently published official report on the work of driving the great twelve-mile Simplon tunnel in Switzerland, it appears that at the beginning of this year one of the two parallel tunnels which really constitute the work had been completed over a distance of 46,996 feet, and the other over a distance of 46,281 feet, or in both cases close on to nine miles. The expenditures on the two drivings, including the lines of access, amounted in round numbers to 9,800,000 francs from October 1, 1901, to September 30, 1902, the fourth year of construction, and for the total of the four years, to 37,800,000 francs. The extremely rapid increase of the rock temperature at one time alarmed the official, going up as high as 129 degrees F., considerably more than had been anticipated; but the bottom of the northern gallery being below the culminating

point of the mountain, it was almost certain that the temperature would not increase any further. The installations for ventilating and cooling the air also gave satisfactory results, keeping the temperature down to between 75 and 82 degrees. It seems almost unnecessary, and yet it may be interesting, to repeat that with its twelve-mile length the Simplon tunnel will be the longest in the world. It will establish direct communication between Paris and Milan, but without the drawback of the heavy grades which characterise the St. Gothard line. The contract made with the Jura-Simplon Railway Company by Messrs. Brandt, Brandauer & Co. guaranteed the completion of one of the two tunnels within five and one-half years. No fixed time was stipulated for the completion of the second tunnel.

THE article on feed-water heaters and purifiers, printed elsewhere in this issue, calls to mind a recent pertinent paragraph to the effect that while the boiler is a steam producer and nothing more, one of the astonishing features of power plant construction is the constant use of the boiler as a water purifier. To a very large extent this is true with the smaller plants, and it would seem as though makers of heaters and purifiers ought to be able to find here many neglected business opportunities capable of being turned to good account. While boiler economy has been the theme of many an article by which steam users have profited, its possibilities have not yet been exhausted.

WITH electricity as the largely preponderating means of power transmission at the present time, special interest is attached to a compressed air transmission system which is being operated in the town of Norwich, Connecticut, by the Continental Compressed Air Company, and with results, so far, apparently satisfactory to all concerned. The Continental Company has a compressor station at Taftville, on the Quinebaug river, about three miles from the furthest point of distribution, and the Taylor system of hydraulic compression is employed, much after the manner followed in the plant at Magog, in Canada, described in this magazine in August, 1901. About fifty engines now running at Norwich are operated with compressed air coming from that station, the engines ranging from 2 to 250 horse-power. There is a practically immaterial loss of air pressure in the transmitting pipe,—an average of about one pound, the ninety pounds at the compressor being reduced to eighty-eight pounds at the furthest point of consumption. Altogether, about 1500 horse-power are supplied in Norwich. The air is used in the engines just as steam would be. No changes have been made in the engines. The air is passed through a heater before entering the engines. As to the cost of the air to consumers, no definite price has yet been fixed upon. At present, in a preliminary way, fifty dollars are charged for a horse-power for a year.

OLD-AGE pensions are matters of recurring interest. It is the need of provision for old age which keeps many a worker on the anxious seat during the greater part of his life, and until the problem of how best to make such provision shall have been generally solved, suggestions bearing upon it are all worth considering. In the *Cosmopolitan Magazine* of recent date Dr. Edward Everett Hale had an article on the subject, in which he writes with reference to American conditions, and more specifically still with reference to conditions in the State of Massachusetts, where a system of poll-tax is still maintained. Every man who is more than eighteen years of age must put $2 a year into the treasury of the State. Thus, in the last year, 1902, every male citizen was made to pay this sum for the services of the town or of the State. This tax was apart from what he paid into the excise on his liquor and spirits, and on his share of

the national tariff, and amounted to more than $2,000,000. "If we divided that sum into pensions of a hundred dollars each," he says, "we should have 20,000 of such pensions. If we paid a hundred dollars to every citizen, man and woman, over sixty-nine years of age, we should have to pay about $125,000. Each one of them would feel that he had been insuring himself in old age by his payments to the Commonwealth. No one of them would feel that he was a beggar or pauper. And as soon as we shall begin upon such an arrangement, so soon will tax-dodging on the part of poll-tax people come to an end. There is not a young man or an old man,—a hobbledehoy or a hobbledehoy's father,—who would not gladly pay his scot, year by year, when he saw the cheer and comfort which such a payment gives, perhaps to a father or mother, perhaps to a grandfather or grandmother. And I do not think even the fairer or weaker sex need decline the $100 which will be paid to each of them. Their case would be a little stronger in the forum of justice if they had paid any poll-tax. As it is, the poll-tax fund paid by the man is sufficient for every payment.

"Simply speaking, the payment of an old-age pension, say of a hundred dollars each to every citizen, male or female, who has passed the age of seventy, does not involve a heavy burden to the State. For where the State has been collecting poll-taxes, it has received from such taxes far more than the pension proposed would require. Let us now consider for a moment the advantages which the State, as an organisation, would receive from such a system. As matters stand, the managers of asylums, whether for the poor, or perhaps for the blind, or the insane, or other invalids, are always at their wits' ends to know what they shall do with the aged people who are crowded upon them. The almshouses of towns and counties are filled in the same way. Now, all these old people are better cared for in the homes of old neighbours, or old friends, very possibly of sons or of daughters, who would receive them and take charge of them humanely if they could receive a little ready money for the extra expense. As society organises itself, a very little money goes a great way in the average household. The moment that it appears that a grandfather or a grandmother has $100 a year to his good, that moment we shall find that the burden thrown upon the State and town in their asylums is reduced by a larger proportion than by the charge made by the pensions upon the treasury. Thus the pension system has the great advantage that it maintains life in homes, and that it abates the necessity for great institutions or asylums."

PHOTO BY CUTEKUNST, PHILADELPHIA

REAR-ADMIRAL GEORGE WALLACE MELVILLE

ENGINEER-IN-CHIEF OF THE UNITED STATES NAVY FROM 1887 TO 1903

SEE PAGE 456

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CASSIER'S MAGAZINE

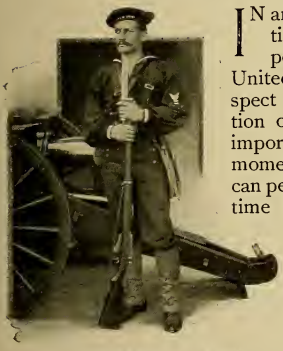
VOL. XXIV SEPTEMBER, 1903 No. 5

THE AMERICAN FIGHTING FLEET

ITS STRATEGIC DISPOSITION

By John Callan O'Laughlin

The grand principle of war is that an army ought always to be ready, by day and by night, and at all hours, to make all the resistance it is capable of making.—*Napoleon.*



IN LIGHT MARCHING ORDER

IN an age of preparation for war the peace policy of the United States with respect to the distribution of its fleet has an importance of great moment to the American people and to maritime nations whose interests may clash with those of the United States. This policy, now nearing consummation, has been little advertised; but it is safe to say that more thought has been given to it than to any other feature of recent naval development. Much has been heard about the types of the latest American battleships, the improvements in guns and armour, and the necessity for more officers and men and the training of those in service; but while public attention has been riveted upon these matters, the United States Navy Department has been quietly gathering the fighting units of the fleet and placing them in strategic positions where they will be able to render effective service, whether in the way of offence or defence.

The organisation of the ideal fleet begins with the designing of the ships that will comprise it; but human ingenuity, constantly striving to increase the destructive power of weapons, makes advances which no nation having interests to protect can afford to disregard. Homogeneity, which has been justly defined as a judiciously regulated harmony of navigability, radius of action, and speed, is the first quality sought by the naval tactician. It could be achieved by the reproduction of one type of ship, irrespective of developments that give superiority. But a power that pursued such a policy would bring upon itself the reproach of non-progressiveness, and non-progressiveness is another way of spelling retrogradation. So the tactician, directing the distribution of the modern fleet, must take into consideration the diverse elements comprising it and effect a union of those which have points of resemblance.

Certain elements are incapable of

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THE LATEST PORTRAIT OF ADMIRAL GEORGE DEWEY, U. S. N., TAKEN BY SPECIAL ARRANGEMENT FOR "CASSIER'S MAGAZINE"

amalgamation, as, for instance, the *Katahdin*, which is the ebullition of a period when the naval world inclined to the superiority of the ram as a weapon of offense, and which possesses no other means of attack, and the dynamite cruiser *Vesuvius* which was built to hurl large charges of high explosives at an enemy. And one might also mention the triple-screw cruisers *Columbia* and *Minneapolis*. The *Katahdin* never had sufficient speed to catch an active enemy, and to-day would be sunk by shell or torpedo before she could get within ramming distance. The pneumatic guns of the *Vesuvius* had a range far less than that of the high-power guns of a modern man-of-war, and could be destroyed before she could fire a projectile.

The triple-screw cruisers *Columbia* and *Minneapolis*, though fast, are no longer mistresses of the sea, and, moreover, the reasoning upon which their construction was based was faulty. It was believed that the operations of these vessels would annihilate the commerce of an enemy, who thus would be compelled to sue for peace; but in modern war victory will be achieved by that nation which gains command of the sea, and command of the sea will be the prize for which armour clads will fight.

REAR-ADMIRAL ROBLEY D. EVANS, COMMANDER-IN-CHIEF OF THE ASIATIC FLEET

REAR-ADMIRAL JOSEPH B. COGHLAN, COMMANDER OF THE CARIBBEAN SQUADRON, NORTH ATLANTIC FLEET

That more attention has not been paid to homogeneity in the building-up of the American fleet is, in part, attributable to the country itself, which, a dozen years ago, feared to build a navy for offence. The *Monitor* saved the Union in the Civil War, and the nation went mad over it, building vessels of the *Monitor* type thirty-three years after the war had closed, and when other nations and even the United States had combined the *Monitor* and the Confederate *Merrimac* and produced the battleship. The earliest first-class American battleships were the *Indiana*, *Oregon*, *Massachusetts*. They were described as coast defence battleships and built as such. Then came the *Iowa*, a "seagoing coastline battleship," whatever that may mean; but the designation allayed the apprehension of timid Congressmen who feared to make a bold declaration in behalf of a formidable navy, and it was in-

MARINES FROM THE NEW BATTLESHIP "MAINE" IN SKIRMISH DRILL

serted in every law authorising vessels of this class until that of July, 1902, when national sentiment was considered strong enough to support appropriations for "seagoing battleships."

In spite of legislative limitation, all the battleships of the United States were built to keep the sea; and the record run of the *Oregon* from San Francisco to Key West, where she reinforced the squadron preparing to meet the Spanish fleet, is a vindication of the sagacity of naval constructors who went as far as liberal interpretation of law permitted. In looking over the characteristics of the battleships in service or building, we find that their displacement ranges from 10,288 to 16,000 tons; their actual speed from 15 to 19 knots an hour, and their radius of action from 4000 to 8000 miles.

There is a variation less serious, fortunately, in the armoured cruisers. The *New York* is the smallest and slowest, having a displacement of 8400 tons and a trial speed of 21 knots, and the *Tennessee* and *Washington*, under construction, are the largest, displacing 14,500 tons. Their speed will be 22 knots an hour.

A nation's fighting strength consists of those vessels available at the moment for action, or which can be gotten ready within a reasonable space of time. Ships under construction must be disregarded, therefore, except as prospective units; and in the policy governing the distribution of the fleet, account is taken only of ships in commission or capable of being put into active service without delay.

This limitation has been an impassable wall to the general board of the navy, which is responsible, under the Secretary of the Navy, for the distribution of the fleet made within the past year. In comparison with the magnitude of the interests requiring protection, the means available are meagre, but the board has disposed of them in a way best calculated to meet possible emergencies. In making the dispositions, consideration has been given necessarily to existing diplomatic conditions and to the naval strength of nations with which there is a possibility of war.

It is now a commonplace to say that the war with Spain established the rank of the United States as that of a power of the first class. But the fact of such recognition found existence in the recognition of strength to maintain that rank. The war brought also an increase of more material obligations. Before 1898 the United States was vulnerable only upon its own coasts. Now it is vulner-

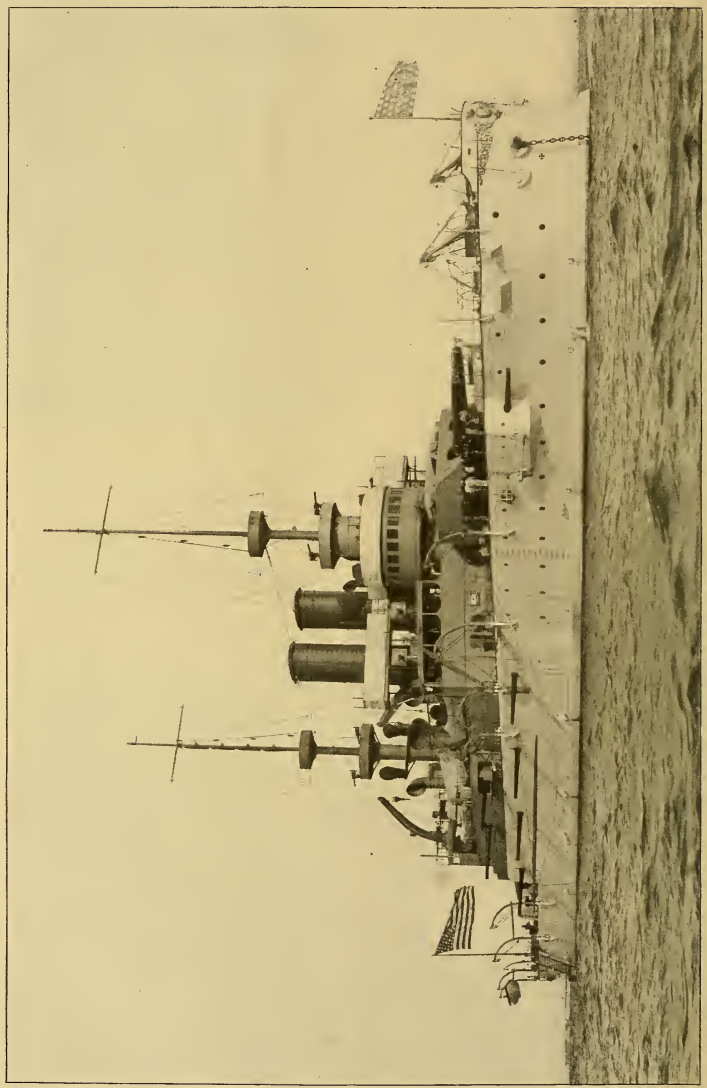
able not only upon those coasts, but in the Philippines, in Guam, in Hawaii, in Cuba, and in Porto Rico, and it will be in a few years in the Isthmian Canal. It has declared for the territorial and administrative entity of China, and the declaration is worth nothing unless it be supported by force. The Monroe Doctrine has been always an object of solicitude.

The nation thus measures its resources and its responsibilities. Out of the tactical calculations may be taken at once the possibility of military invasion. It is command of the sea that will determine the victor in the future war, as it was command of the sea which determined it in the war with Spain. Looking over the list of maritime nations which may become enemies of the United States, we eliminate Spain, because of her crushing defeat and the impossibility of her recovery to do harm, and Great Britain, which cannot afford war with the United States, first because it would involve the danger of intervention by European governments anxious to destroy or, at least, cripple British power; second, because of the disturbance of her commercial and financial interests; and, third, because of the certainty that Canada would be invaded and probably conquered.

REAR-ADMIRAL JAMES H. SANDS, COMMANDER OF THE COAST DEFENCE SQUADRON, NORTH ATLANTIC FLEET

With Russia and France the United States has possible points of conflict in

KIT INSPECTION ON THE "MASSACHUSETTS"



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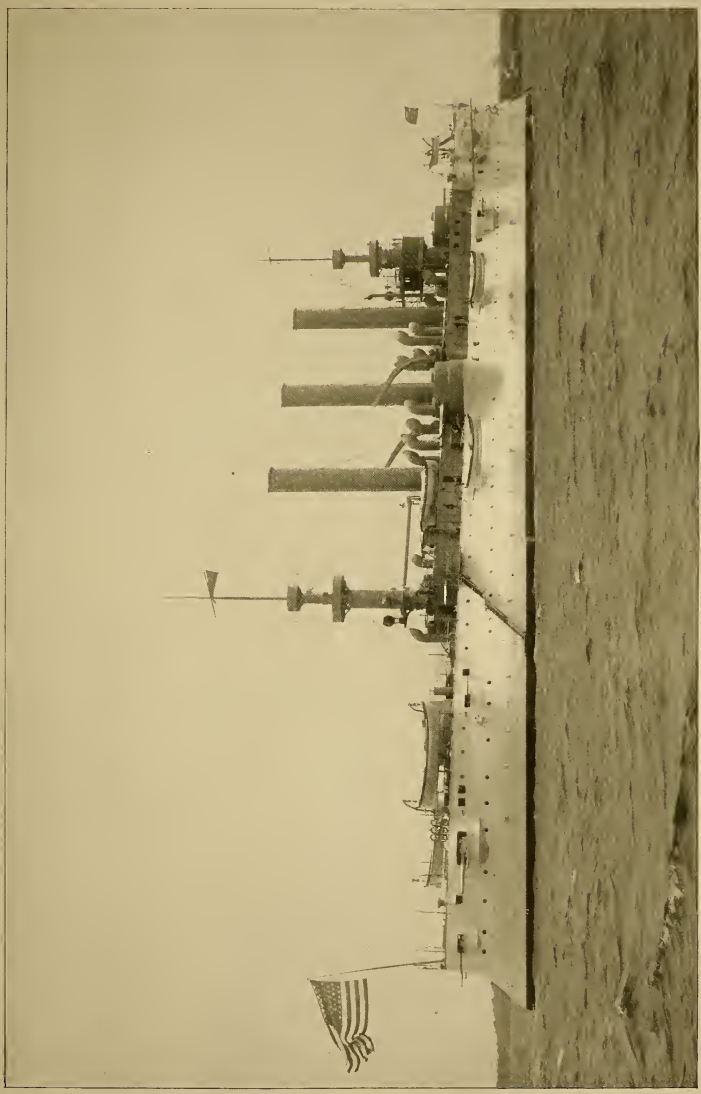
THE NEW BATTLESHIP "ALABAMA"



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THE ARMOURED CRUISER "BROOKLYN"

A FORECASTLE GROUP ON THE "ATLANTA"

China, so that they are to be considered; but the chance of war with them, especially with Russia, which has been America's lifelong friend, is so remote that now it is given only cautionary attention.

Germany, Austria, and Italy, forming the Triple Alliance, are the nations which especially concern the United States; not that the Triple Alliance extends to American questions,—it does not, and Italy would refrain, it is believed, from participating in a war with the United States. Germany's attitude is so well known that it is unnecessary to describe it. Austria has made no secret of her hatred of America, a feeling due to commercial jealousy and intensified by the downfall of Spain. Undoubtedly she would give to Germany whatever assistance she could within the bounds of neutrality, and might even exceed them. But Austria is torn by internal dissension, and the price of a foreign war might be disruption.

At the present time the United States has nothing to fear from Japan. That government welcomed the American occupation of the Philippines because of the belief that the United States, its foot at the gateway of China, would not stand idly by and permit partition of the Empire. Japan is contesting Russian occupation of Northern China and Korea; but the Czar has almost won Manchuria, which is bound to his Empire by girders of steel,—the branch line of the Trans-Siberian Railroad, which connects St. Petersburg with Port Arthur and Dalny, the one a naval stronghold, and the other a commercial port lying at the southern end of the Manchurian peninsula. Japan has a treaty of alliance with Great Britain for the preservation of the territorial integrity of China and the maintenance of the "Open Door." Russia, France, and Germany, in spite of their declarations, are regarded as the nations eager to carve up the Empire. The United States is the balance of power. Japan may be disposed some day to dispute

American supremacy in the Pacific, but that day is distant.

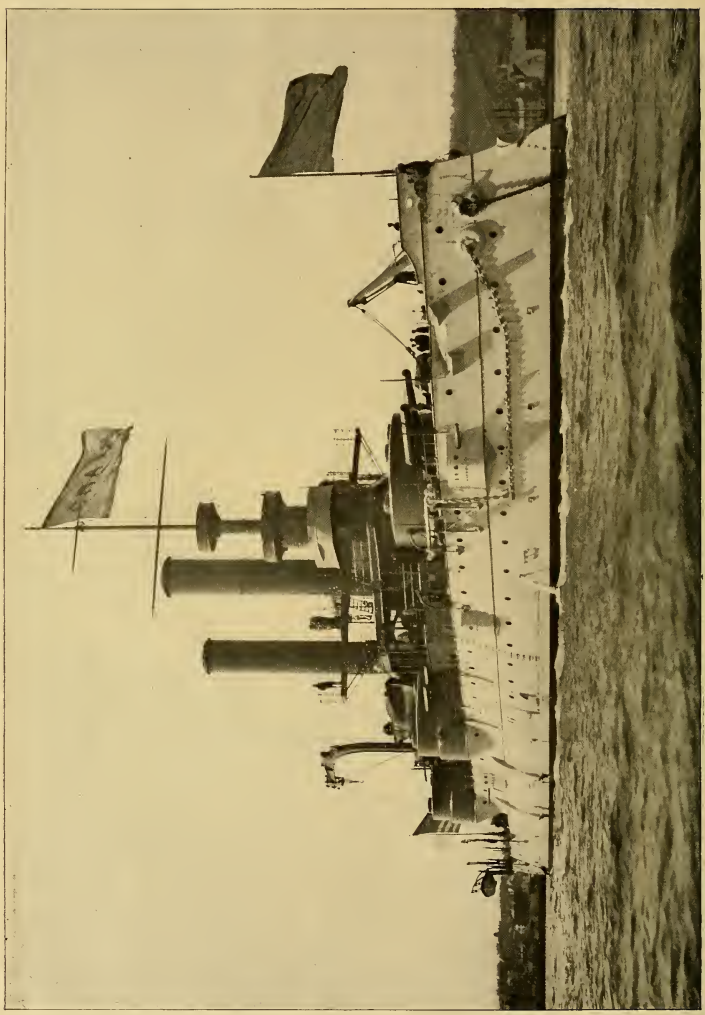
The commerce of the United States pulses to every land, and it is a temptation for the government to dispatch warships to foster and protect it. This was the policy before, and for a time after, the war with Spain. To fritter away the naval strength of the nation by such a course was advantageous commercially, but unpardonable tactically. It is easy to recall the hasty organisation of squadrons on the outbreak of the war with Spain; the dispatch of reinforcements and ammunition to Dewey, on the China Station; the formation of the flying squadron under Schley; and of a coast defence, or, as it was then called, the northern patrol squadron, which would have proved as effective in repelling a single well-manned armoured cruiser as was the Spanish squadron when subjected off Santiago to the fire of the American fleet.

The tactical manœuvres of the fleet prior to the war were limited to the armour-clads of the North Atlantic Station, which, under the command of Rear-Admiral Bunce, and later of Rear-Admiral Sicard, were brought to a reasonable degree of efficiency. The remainder of the fleet had never cruised in squadron, or so rarely that the experience was of no practical value.

REAR-ADMIRAL PHILIP H. COOPER, COMMANDER OF THE NORTHERN SQUADRON, ASIATIC FLEET

Following the war with Spain there was a renewal of manœuvres by the North Atlantic squadron; but the neg-

RAPID FIRE GUNS AND CREWS ON THE ARMOURED CRUISER "BROOKLYN"



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THE SEA-GOING BATTLESHIP "IOWA". BUILT BY THE WM. CRAMP & SONS SHIP AND ENGINE BUILDING CO., PHILADELPHIA

THE ENGINEERING FORCE OF THE BATTLESHIP "OREGON"

lect to train the whole fleet, manifested before the struggle, was maintained after it. Some excuse for this failure to observe elementary principles existed in the Philippine insurrection and in China, when the Boxer revolt held the attention of the civilised world. To aid in the suppression of the insurrection, and also to assert American purpose to retain the archipelago, the battleships *Iowa* and *Oregon* were detached from the North Atlantic Squadron, after the signature of the Spanish peace protocol, and sent to the Pacific. The *Iowa* was subsequently ordered to return to the South Atlantic, where she became flagship of the squadron in those waters.

The *Oregon* remained in the Far East until the termination of the Boxer revolt, when she proceeded to Bremerton, Washington, for repairs. The *Kentucky*, placed in commission, was dispatched to the Far East, where she received the flag of the commander-in-chief. The *Wisconsin*, commissioned at San Francisco, was designated as the flagship of the Pacific Station. The *Illinois*, immediately after entering active service, became the flagship of the commander-in-chief of the European Station. The President was induced to approve the use of battleships as flagships. Thus the armoured strength of the United States Navy, most effective, of course, when acting as a unit, was dispensed over the globe, and each battleship was in a position to be cut off and compelled to enter into action with an enterprising and superior enemy.

President Roosevelt's eyes were opened to the inadvisability of his order, and he revoked it. Mobilisation of the battleships was directed, in spite of many protests. The order was executed in the Atlantic after the recent manœuvres in the Caribbean Sea, in which the North

THE SUBMARINE TORPEDO BOAT "ADDER"

Atlantic, South Atlantic and European squadrons participated. Admiral Dewey has said, without intending offence to Germany, that those manœuvres were an object lesson to that country. But the results growing out of them are of far greater significance, for the foreign naval tactician understands the tremendous increase in the power of the American fleet caused by the collection of the battleships of the three squadrons named. The battleships in the Pacific Ocean have just effected mobilisation.

The history of future naval war may be read in the past, and in the light of what has been it is evident that the Caribbean Sea will continue to be the battle ground upon which nations will fight for supremacy in the western hemisphere. The importance of this region will be increased when the Isthmian Canal is completed. Admiral Dewey has described the sea as an American lake, and another distinguished naval officer has been credited with saying that it will be to the United States what the Mediterranean is to Great Britain.

This latter comparison is not entirely justified. The Mediterranean is the great pathway to Britain's commercial and colonial supremacy. That the Isthmian Canal will increase the importance of the Caribbean Sea to the United States there can be no question. It will be the road that American commerce will take between the Atlantic and Pacific coasts, from the Atlantic coast to the Pacific coast of South America, the Pacific islands and the Far East, and from the Pacific coast to the eastern coast of South America and Europe.

The general board has recognised the present importance of this sea by stationing there a division of the North Atlantic fleet, consisting of cruisers and gunboats and a transport carrying marines. This division is always ready to proceed to a country in the throes of revolution, and, if conditions require it, the marines are disembarked. Rarely is a single ship sent; the squadron goes, —an important difference. With such a force at hand, prepared to protect British and Continental, as well as American interests, excuse for European intervention is absent. Moreover, the vessels moving together have an opportunity to drill. With the Isthmian Canal completed and in service, this squadron will undoubtedly be of a size commensurate with the importance of the interests in its care. It will probably never be of the same strength as that which Great Britain is compelled to maintain in the Mediterranean. The shores washed by the waters of the European sea are those of France, Britain's bitter enemy; of Italy, whose coolness toward

REAR-ADMIRAL BENJAMIN P. LAMBERTON, COMMANDER-IN-CHIEF OF THE SOUTH ATLANTIC SQUADRON

the British government is partially responsible for the recent rearrangement of the latter's naval force; and of Austria, which is linked with Germany in dislike of King Edward's people. The United States has no such enemies in the Caribbean Sea. Germany, Austria, and Italy have not even coaling stations there. The Monroe Doctrine will prevent those countries, or any other, from acquiring territory on the western hemisphere.

Protection of the interests of the United States in the Atlantic Ocean are

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A RECENT VIEW OF THE BATTLESHIP "TEXAS"

to-day entrusted to a battle fleet, the first of its kind ever organised by the United States. There is a second line of defence, consisting of a home or coast defence squadron, which is made up of the second-class battleship *Texas* (flagship), monitors, and torpedo-boats. But every great captain has recognised that the best defence is offence, and it is the battle fleet upon which the hopes of the country must rest in the next war. It will be the duty of that fleet to seek the enemy when he comes within the circle of its influence and to offer him battle. So inadequate is the navy to-day that there is no reserve which can be drawn upon,—a deficiency the United States will regret in future hostilities when easy victory will be impossible and ships will be more or less damaged. If the American fleet be defeated, then the Home Squadron must endeavour to assist the fortifications to prevent a successful assault upon any of the Atlantic or Gulf ports.

In Europe and South America the United States needs to maintain only squadrons to observe and to protect its commerial interests. "Westward the course of Empire takes its way," is an aphorism that has truly marked American progress. The war with Spain caused the United States to leave the continent and to forge a chain across the Pacific. That chain is to America what Britain's chain, between her Isles and her Indian and Australasian Empire, is to her. It cannot, must not, be broken. The Pacific Ocean fifty, nay ten, years ago was relatively unimportant. To-day its importance is tremendous; within a generation it will have a value to the world now hardly dreamed of. The geographical position of the United States has given the country an initial commercial and strategic advantage which is being seized, and which, the character of the American people proves, will be pressed.

Therefore, while existing conditions impose the necessity of establishing and maintaining a strong battle fleet in the North Atlantic, the United States naval authorities have not lost sight of American obligations in the Pacific. Distant as is the Pacific slope from any nation apt to engage the United States in war,

REAR-ADMIRAL HENRY GLASS, COMMANDER IN-CHIEF OF THE PACIFIC SQUADRON

REAR-ADMIRAL CHARLES S. COTTON, COMMANDER-IN-CHIEF OF THE EUROPEAN SQUADRON

no imperative need exists for a battle fleet there, and a cruiser squadron is considered sufficient for drill and protection of American interests along the revolutionary coast of Central America. A South Pacific squadron is a desirability, but its formation can be postponed until more ships are built. The Eastern Pacific, which is to-day the prominent point of the world's naval activity, is especially important to the United States

REAR-ADMIRAL A. S. BARKER, COMMANDER-IN-CHIEF OF THE NORTH ATLANTIC FLEET

because of the Philippines and China. The Navy Department has organised on this station a battle fleet lacking homogeneity, for there are only three battleships available, and they are supported by two monitors, and a cruiser squadron, which is homogeneous.

It is worth while to recall how the Far East has grown in the eyes of the world. Ten years ago Great Britain believed four cruisers and fourteen smaller vessels ample to protect her interests in that section. In 1897 she had but one battleship in Chinese waters. Now she has a squadron, regarded as a unit of high fighting value, consisting of five armoured ships, four of which are battleships of 12,950 tons each, and one a modern armoured cruiser of 12,000 tons. Russia is weakening her Baltic Sea defence to strengthen her Far Eastern fleet, a step imposed upon her by the British-Japanese alliance. France, also, has increased her strength in China. Japan keeps her entire navy at home. Germany has observed the policy of concentrating her men-of-war in North Sea waters, and has only three ships of fighting value in the China Sea,—an armoured cruiser and two protected cruisers.

The strength of the American fleet and its distribution in 1897 and its strength and distribution in 1903 are shown in the following table:—

NORTH ATLANTIC FLEET

1897	1903
BATTLE FLEET	BATTLE FLEET
(None)	Battleships
Battleships	Maine (flagship)
Indiana	Kearsarge
Massachusetts	Alabama
Iowa	Illinois
Texas (2d class)	Iowa
Armored Cruisers	Indiana
New York (flagship)	Massachusetts
1897	1903
BATTLE FLEET	BATTLE FLEET
Brooklyn	Missouri (to be commissioned)
Maine	Gunboat
Unprotected Cruisers	Scorpion (tender)
Montgomery	
Detroit	
Marblehead	
Vesuvius (dynamite cruiser)	
Monitors	
Puritan	
Terror	
Gunboats	
Wilmington	
Fern	
CARIBBEAN SEA DIV.	CARIBBEAN SEA DIV.
(None)	Protected Cruisers
	Olympia (flagship)
	Atlanta
	Gunboats
	Marietta
	Vixen
	Marine Transport
	Panther
COAST DEFENCE DIV.	COAST DEFENCE DIV.
(None)	Battleship, 2d class
	Texas (flagship)
	Monitors
	Arkansas
	Florida
	Nevada
TORPEDO BOAT DESTROYER FLOTILLA	TORPEDO BOAT DESTROYER FLOTILLA
(None)	Destroyers
	Decatur (flagship)
	Bainbridge
	Barry
	Chauncey
	Dale

SWORD EXERCISE

1897	1903
TRAINING SQUADRON	TRAINING SQUADRON
(None)	
Training Ships, Atlantic Waters	Training Ships, Atlantic Waters
Essex	Buffalo
Alliance	Prairie
Monongahela	Dixie
Standish	Yankee
	Hartford
	Topeka
	Alliance
	Lancaster
	Monongahela
	Columbia (flagship)
	Amphitrite
Training Squadron, Pacific Waters	Training Squadron, Pacific Waters
(None)	Adams
Trainingship Pacific Waters	Alert
Essex	Pensacola
	Ranger

ASIATIC FLEET

BATTLE FLEET	BATTLE FLEET
(None)	Battleships
Protected Cruisers	Kentucky (flagship)
Olympia	Wisconsin
Boston	Oregon
Gunboats	Monitors
Yorktown	Monterey
Machias	Monadnock
Petrel	
Monocacy	
CRUISER SQUADRON	CRUISER SQUADRON
(None)	Protected Cruisers
	New Orleans
	Albany
	Cincinnati
	Raleigh

1897	1903
PHILIPPINE SQUADRON	PHILIPPINE SQUADRON
(None)	Auxiliary Cruiser
	Rainbow (flagship)
	Gunboats
	Twenty-five
COLLIERS AND SUPPLY SHIPS	COLLIERS AND SUPPLY SHIPS
(None)	Seven

EUROPEAN SQUADRON

CRUISER SQUADRON	CRUISER SQUADRON
(None)	Armoured Cruiser
Protected Cruisers	Brooklyn (flagship)
San Francisco (flagship)	Protected Cruisers
Minneapolis (triple screw)	Chicago
Cincinnati	San Francisco
Raleigh	Baltimore
Gunboat	Gunboat
Bancroft	Machias (tender)

SOUTH ATLANTIC SQUADRON

CRUISER SQUADRON	CRUISER SQUADRON
(None)	Protected Cruisers
	Newark (flagship)
	Unprotected Cruisers
	Detroit
	Montgomery
	Marblehead
	Gunboat
	Gloucester (tender)

PACIFIC SQUADRON

CRUISER SQUADRON	CRUISER SQUADRON
(None)	Armoured Cruiser
Battleship	New York (flagship)
Oregon	Protected Cruiser
Protected Cruiser	Boston
Philadelphia (flagship)	Gunboats
Monitors	Bennington
Monterey	Concord
Monadnock	
Sloops	
Alert	
Marion	

Another indication of the attention that the naval authorities are giving to the fleet may be found in the number of officers of flag rank now at sea. The asterisks show the new commands created during the past two years:—

Rear-Admiral Albert S. Barker, commander-in-chief of the North Atlantic Fleet.

* Rear-Admiral Joseph B. Coghlan, commanding Caribbean Squadron, North Atlantic Fleet.

* Rear-Admiral James H. Sands, commanding Coast Defence Squadron, North Atlantic Fleet.

* Rear-Admiral William C. Wise, commanding Training Squadron in North Atlantic waters.

Rear-Admiral Robley D. Evans, commander-in-chief of the Asiatic Fleet.

* Rear-Admiral Philip H. Cooper, commanding Northern or China Squadron, Asiatic Fleet.

* Rear-Admiral Yates Stirling, commanding the Philippine Squadron, Asiatic Fleet.

* Rear-Admiral Benj. P. Lamberton, commander-in-chief of the South Atlantic Squadron.

Rear-Admiral Charles S. Cotton, commander-in-chief of the European Squadron.

Rear-Admiral Henry Glass, commander-in-chief of the Pacific Squadron.

It may be asked,—Is the fleet, as at present disposed, able to take care of the vital interests entrusted to it? There is but one answer, and that emphatically No! The disposition of the fleet cannot be improved. The elements comprising it are good. The morale of its personnel is high. Yet it is absurdly weak in comparison with the magnitude of American interests and the requirements which war will create.

An appreciation of the naval necessity of the country has induced Congress to make substantial increases in the past five years.

Other nations, Germany particularly, are pledged to shipbuilding programmes which will make them superior to the United States. Emperor William has based his plea for a strong navy on the ground that Germany wants peace on the sea. This is also the desire of the United States, and the way to assure it is to organise a force so strong that attack would invite disaster. This does not mean that the United States should have a naval armament out of proportion to its interests. It means that, taking into consideration American responsibilities, the country should provide a navy which will enable it, unfettered by foreign threat, to observe them, and to do so in the way civilisation and humanity dictate.

THE RAILWAY TOWN OF CREWE

THE HOME OF THE LONDON & NORTH-WESTERN RAILWAY WORKS,—THE LARGEST IN THE WORLD

By Charles S. Lake

THE town of Crewe, as we know it nowadays, is wholly and entirely a creation of the railway. Up to sixty years ago the place was, to all intents and purposes, unknown, insignificant in size, and unimportant in character; but already the day had dawned which should mark the commencement of a new era, a period of transformation which has resulted in the conversion of the once secluded hamlet into the present thriving and populous township, world-famous as providing the site for the largest and most important railway workshops in existence.

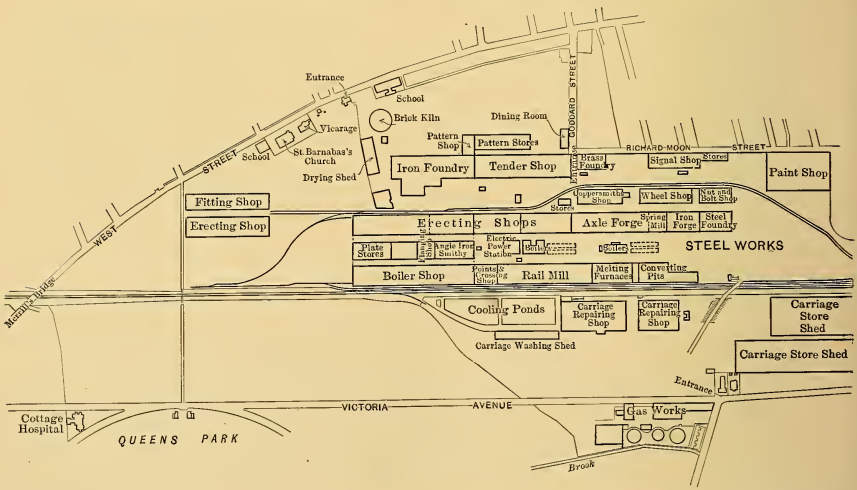
Although the primary object which the author has in view in the preparation of the present article is that of conveying some idea of the magnitude and capacity of Crewe Works as they at present stand, a brief description of the vast establishment and the town which it maintains, from a historical aspect, will not, perhaps, be without interest.

It was in March, 1843, that the nucleus of what was predestined to develop into the mammoth establishment of to-day was formed. At that early period in the history of railway communication Crewe was served by the Grand Junction Railway, which in 1846 was amalgamated with several other railways, including the Liverpool & Manchester and London & Birmingham, and the whole became known as the London & North-Western Railway. The length, in 1846, of the newly-formed, complete system was 420 miles, whilst at the present time it is 1962, being second only in this respect to the Great Western, of which the large total of 2655½ miles will be better understood when it is pointed out that no less than 1283 miles of this,—or very nearly 50 per cent.,—are contributed by the single-track lines in the western districts of England.

For the purpose of maintaining the locomotive, carriage, and waggon stock of the Grand Junction Railway the first set of shops was established at Crewe in 1843, as already stated, and these still remain intact, being known at the present time as the "Old Works," to distinguish them from the other two groups of buildings which are, respectively, described as the "Deviation Shops" and the "Steel Works," for reasons which will be referred to later.

It took but a very few years, immediately subsequent to 1843, to demonstrate that the demands of the Locomotive Department were altogether outgrowing the capabilities of that section

THE OFFICES OF THE CREWE WORKS



A GROUND PLAN OF

of the works allotted to their requirements, and as a consequence of this the Waggon Department was removed from Crewe to Ordsall Lane, Manchester.

In 1853 a further addition was made to the Crewe establishment by the construction of works for the manufacture of rails, and in that year also the Waggon Department was again removed, this time to Earlstown, Lancashire;

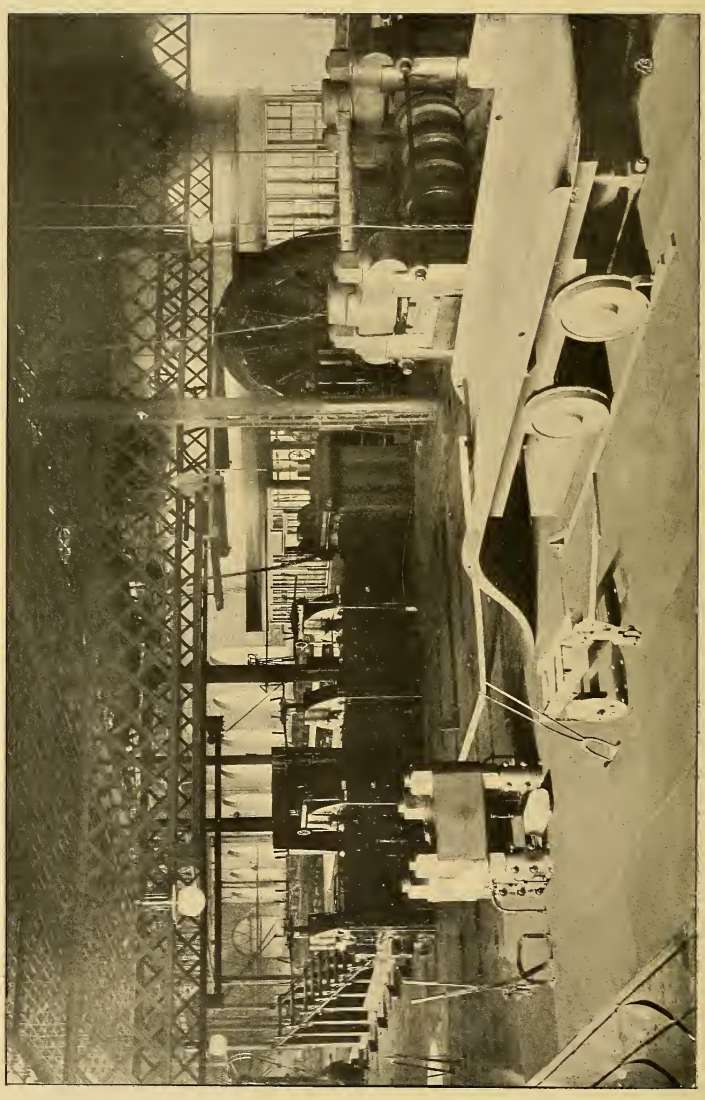
where it has remained to the present day. In 1857 an amalgamation of the northern and north-eastern divisions of the London & North-Western Railway was effected, and Crewe then became the centre of the Locomotive and Carriage Department of the northern division of the line, whilst the locomotive headquarters of the southern division were at that time located at Wolverton.

Two years later the Locomotive Department was again urgently requiring additional accommodation at Crewe, and as a result the Carriage Department was compelled to follow in the footsteps of its previous neighbour, the Waggon Department, and a new home was found for it at Saltley, near Birmingham, in 1859. And so it came about that the Locomotive Department had, in sixteen years from the establishment of the original works, ousted the two contemporaneous departments, and had secured to itself the whole of the space which had previously been allotted to the three distinct branches of work.

These were even yet early days in the history of the London & North-Western Railway, and the spirit of amalgamation was still in the air, whilst administrative changes were constantly being made as the huge concern settled itself down on lines which later events proved to be of a permanent character.

The year 1862 brought about further and most important developments. The locomotive department of the southern division and that of the northern division of the railway were then amalgamated, and the resources of Crewe and Wolverton were united, the former place being, once and for all, definitely selected as the headquarters of the Locomotive Department throughout the line, whilst the Carriage and Waggon Departments were accommodated at Wolverton and Earlestown, respectively. Mr. Ramsbottom, who till then had occupied the position of locomotive superintendent of the northern division of the line, now became locomotive superintendent and mechanical engineer for the whole system. This, then, was the position in 1862,

THE CREWE WORKS



A VIEW OF THE RAIL MILL

and, so far as the works are concerned, it has remained thus to the present time.

Simultaneously with these changes taking place, additional workshops were erected at Crewe for the use of the Locomotive Department, in lieu of those vacated at Wolverton. The question of venue having thus been definitely decided, the development of Crewe Works proceeded apace.

In 1864 a very important addition to the establishment was made by the erection of works for the manufacture of Bessemer steel. In order to do this, fresh ground had to be broken, as all the available land at the Old Works was then occupied. A site in the immediate vicinity of the Chester & Holyhead main line, and distant about half a mile from the Old Works, was selected. Up to this time the Chester & Holyhead trains had run through the centre of the works; but, owing to the increasing traffic both in the works and on the railway, it was deemed advisable to divert this portion of the line so as to place it entirely outside of the works. As a result of the carrying out of this scheme a large tract of land situated between the original main line and the new loop was made available for building or other purposes, and advantage was taken of this fact to erect additional workshops, which, from the time of their completion, have always been known as the "Deviation Shops," owing to the position they occupy with relation to the deviated lines.

To these shops the millwrights, pattern-makers, and moulders were removed from the Old Works towards the end of the year 1867. But even with all these continued improvements and additions the development of the railway was such as to make it necessary to still further extend the size and scope of the works.

In 1870 a new boiler shop and smithy were built at the steel works, in close proximity to the shops which had previously been erected at the time Wolverton was ceded to the Carriage Department, and later,—namely, in 1879, —the tender building and repair shop and the engine painting shop were removed to larger premises, also at the steel works.

At this juncture the directors decided to discontinue the practice of placing outside contracts for the manufacture of their signals and signalling plants, and in order to provide accommodation for this new department, the old tender shop was altered for the purpose. In 1884 it became necessary to erect more commodious premises at the steel works for the Signal Department, and in these shops the whole of the signalling apparatus for the London & North-Western Railway, including cabins, signals, and locking gear, are manufactured.

In 1871 Mr. Ramsbottom, who had taken such an important part in the development of the works up to that time, retired from the service of the company, and Mr. F. W. Webb, who, prior to 1866, had been Mr. Ramsbottom's chief assistant, was appointed as his successor, retiring, in turn, on July 1 of this year. The foregoing briefly outlined sketch of the Crewe Works from a historical standpoint will suffice for the purpose of indicating the steady rate of progress which was maintained from the time of the original commencement in 1843 to that of Mr. Ramsbottom's retirement in 1871, and since Mr. Webb's taking up the reins of government in that year this development has been continued in an even more marked degree, so that at the present time the covered area of the whole establishment is 48 acres and the total enclosed space, 137 acres, whilst the capacity of the works, with regard to output, has grown to altogether unthought-of proportions, constant employment being found for over 7500 persons.

The visitor to the Crewe Works at the present time needs all the concentrative ability of mind of which he may be in possession, if he is to obtain anything like an adequate conception of the vast character of the establishment and the multitudinous nature of the operations which are daily carried out there. Before one has proceeded far beyond the portals of the handsome general offices (into which he is usually ushered as a first step) he is impressed by the

extraordinary amount of bustle and activity which surrounds him on every side. His acquaintance with the interior of this department need be only very slightly advanced before he can easily perceive that everything is ordered upon the highest of systematic principles and carried out in the most methodical and business-like manner.

Upon entering the main doorway at the frontage facing on Chester Bridge the visitor wishing to gain access to that part of the building in which are situated the offices of the chief mechanical engineer and his principal assistants descends a few steps and finds himself in a lengthy corridor extending in slightly curved form for a considerable distance. On the left hand side of this corridor are the various apartments occupied by the chief officials and their clerical staffs.

On the first floor are the accountant's office, the stores office and the laboratory and photographic departments. The drawing office is situated on the ground floor, commencing at the end of the corridor already referred to and extending for 200 feet in the direction of the steel works. The width of this apartment is 30 feet, giving a floor area of 6000 square feet, affording ample accommodation for the large staff of draughtsmen and others employed there.

The whole of the offices are incorporated under the one roof, and are lighted by electricity. The principal frontage of the building, no less than 525 feet long, is towards the works line (originally Chester & Holyhead Railway), alongside of which is a footpath leading to the works.

In order to approach the steel works it is necessary, on leaving the offices, to turn towards the right, and after a few minutes' walk, or a short ride in a "Crewe cab," the steel works yard is reached. Here all the raw material required in the process of steel manufacture is stacked in close proximity to the furnaces, to which it is conveyed on trolleys hauled by small locomotives of special design.

The first building to be entered is one containing two 35-ton Siemens-Martin furnaces, the steel from which is chiefly used for axles, tires, etc. We next come to the converting house of the Bessemer steel plant. It is about two years since the Bessemer process was last used at Crewe. Both it and the Siemens-Martin process were simultaneously employed for a number of years, but it was decided to abandon the former for the latter system, which at the present time is capable of producing 50,000 tons of steel per annum.

After leaving the Bessemer plant we come to a range of seven 25-ton steel melting furnaces, and the gas for these and for the reheating and other furnaces is supplied by fifty eight Wilson gas producers, the gas being conveyed to its various points of use by means of underground flues. Each furnace is fitted with powerful hydraulic machinery for handling the ladles.

The molten metal is delivered from the furnace into a ladle capable of holding 25 tons, suspended from an overhead trolley running at right angles to the narrow gauge railway on the ground below. A train of flat iron trucks, upon each of which are mounted six moulds and a central tube, or "runner," for receiving the heated metal, is brought into position with the leading truck immediately beneath the ladle.

All being in readiness, the word is given, and the man in charge of the apparatus overhead raises a plug in the bottom of the ladle by means of suitable mechanism, allowing the seething metal to flow into the runner below and thence into the moulds, entering them from the under side. After one set of moulds has been filled, the trucks are moved forward to reach the next set, where the operation is repeated, and so on until the entire number of moulds throughout the train have been filled, by which time the miniature narrow gauge locomotive has been attached and immediately starts on its journey to the rail mills, where the ingots are released from the moulds and the train is then at liberty to return to the steel house.

In order that the whole series of operations which are involved in the manufacture of rails, from the time of the in-

gots being formed to that of the completion of the rail, may be followed, the best plan is to accompany the train bearing the moulds to its destination, and there await the rolling processes which subsequently take place.

Before doing so, however, a few minutes may be spared for a glance at the pumping engines which are used for supplying the necessary power for the flanging presses, cranes, and hydraulic rivetters throughout the works. The engines are remarkable, inasmuch as the whole of the details of their construction,—cylinders, crankshaft, and motion generally,—are in every respect similar to those of the "D.X" class of goods locomotives on the London & North-Western Railway; therefore, the same drawings and patterns were used, resulting in a considerable saving in time and material. These engines pump to a pressure of 2000 pounds per square inch, and on occasions even exceed that figure, running up to 2200 pounds.

There are two additional sets of pumping engines,—also with "D.X" details,—engaged in providing power for the hydraulic lifts, cranes, capstans and other machinery of lighter description. The water from these is conveyed by means of underground pipes to all parts of the works at a pressure of 400 pounds per square inch.

The rail and cogging mills were originally laid down in 1875 for rolling 30-foot lengths of rails; but as heavier sections and greater lengths became a necessity, the mills were entirely reconstructed in 1892 and many improvements added. The ingots, 3 feet 4 inches long and 14 inches square, on coming from the Siemens-Martin furnaces, and after reheating in the adjacent reverberatory furnaces, are passed through the cogging mill five times, which reduces their section to 10 × 7½ inches, whilst their length is thus, of course, very materially increased.

By the time they are ready to be passed through the first of the finishing rolls they have been reduced to 5 × 5½ inches, and after a series of five more passes they emerge in the form of a standard rail, approximately 60 feet in length, and weighing 90 pounds to the yard.

Since the adoption of the 60-foot rails it has been found necessary to provide some means of quickly returning the rails to the rolls after their passage in one direction has been completed, and for this purpose an inclined plane, with loose rollers, is provided, which comes into use only during the last stages of manufacture. This device can be plainly seen by referring to the illustration on page 396.

On emerging from the rail mill, the rail is conveyed by means of "live" rollers at the floor level to a circular saw, where it is cut to the required length. It is then dragged by mechanical means on to a rail bed and left to cool. Afterwards it is taken to a machine where it is straightened, and from there to drilling machines, at which the fish-plate bolt holes are drilled in each end. The finished rails are stacked up ready to be loaded into waggons for conveyance to the permanent way stores or to such parts of the line where they may be required.

All the many operations necessary in the handling of rails, from the time they leave the reheating furnaces until they are delivered in a finished state, are effected by steam or hydraulic machinery. The cogging mill is driven by a pair of vertical reversing engines, with cylinders 30 inches in diameter by 42 inches stroke, and the rail mill by a Corliss engine of about 1200 horse-power.

The visitor next proceeds to the "Points and Crossings Shop." As its name implies, this shop is principally devoted to the manufacture of points and crossings required for the permanent way. There are several drilling, slotting, and planing machines in this department, besides others of special design for slotting and milling the parts of diamond crossings.

The boiler shop is next entered, and this, if not the largest of the many spacious shops at Crewe, is one of the finest and most adequately equipped departments in the whole of the works. Its

THE 2000-TON HYDRAULIC FORGING PRESS

length is 673 feet, its width, 107 feet, and within its walls all the most modern appliances required for the purpose of building and repairing locomotive boilers are to be found. The normal output of the shop per annum is about 200 new locomotive boilers, besides which the necessary repairs are made for the boilers of over 3000 locomotives.

Mr. Webb had long been a believer in the adaptability of steel for boiler purposes, and since 1872 over 5600 boilers constructed of that material have been turned out of the Crewe Works without one single case of rupture having occurred. This constitutes, in the opinion of the author, an unanswerable argument in favour of the use of steel in this field,—something which is looked upon with considerable misgiving in

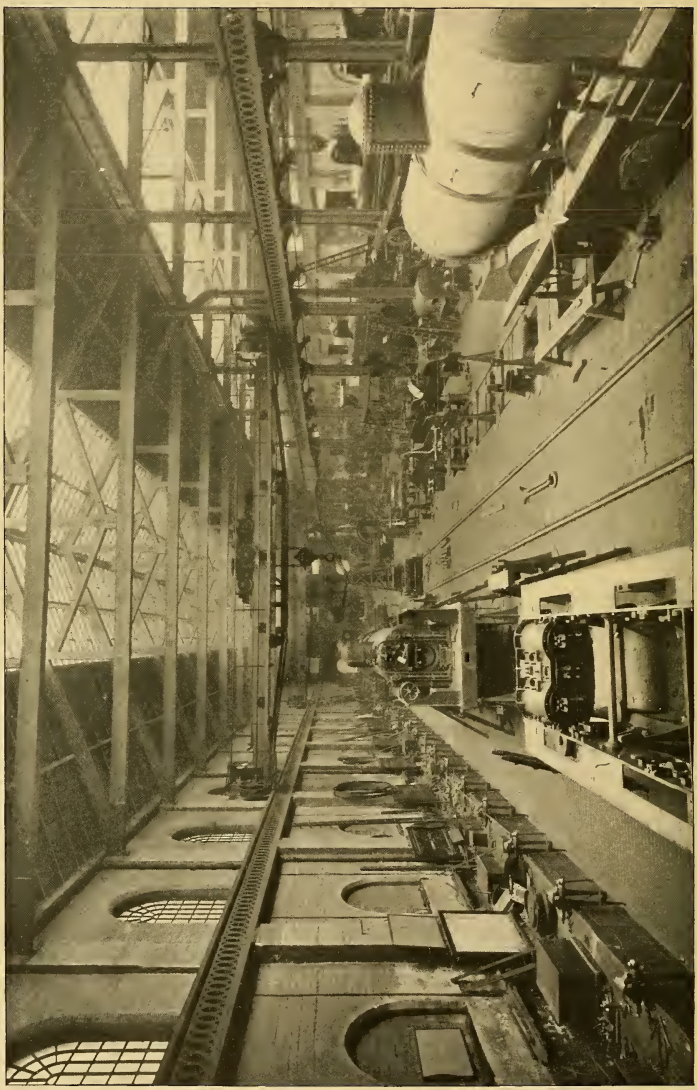
certain quarters. Large numbers of stationary and other boilers, required for various purposes throughout the London & North-Western Railway system, are built and repaired under the same roof as those required for the locomotives; quantities of steel girders also are turned out, both plate and lattice, for warehouses, roofs, foot-bridges, and other service, some having spans of over 70 feet in length. All this extraneous work is carried out without in the slightest degree interfering with the ordinary locomotive boiler work, for which the shop is, of course, primarily intended.

It is on record that as long ago as 1879 forty-two girders, each 32 feet long, were constructed (including the manufacture of the steel and the rolling and building-up operations) within the space of seven days. These were used to replace the Llandulas Viaduct, on the Holyhead line, which was swept away by a storm in the year referred to.

About midway in the length of the boiler shop roof is a raised portion or dome, and a 15-ton electric crane is there fitted, in order that the longest boilers (namely, those of the "Greater Britain" type passenger engines and the eight-coupled compound goods engines) can be riveted up in a vertical position, thus greatly facilitating the handling of the tools. A very clear conception of the size of these boilers can be obtained by seeing them suspended in this manner, as they then appear to be of far greater length than when built up with the engine and in running position. In addition to the just-mentioned crane there are two others of 10 tons each, also electrically operated.

A PART OF THE BOILER SHOP

Nearly all the riveting in the boiler shop is performed by hydraulic machin-



A VIEW OF THE ERECTING SHOP

ery, both fixed and portable. There are also a number of shearing, punching, tapping, drilling, and pneumatic calking machines, and plate-bending rolls.

In an extension of the boiler shop forming an arcade between that and the flanging shop the chimneys for the locomotive engines are made. These are of wrought iron with cast-iron caps, the latter being galvanised before being painted. Adjoining this arcade the fencing used along the sides of the railway at various points is made. Square bars are used for this purpose, edge on towards the front, and each bar is provided with a "spear" head. This fencing is produced at a very rapid rate in lengths of 9 feet 6 inches, pneumatic riveters being largely used in its construction. Upwards of 1100 men are employed in the boiler department, which is one of the busiest in the whole establishment.

In the flanging shop, which is adjacent to the boiler department, all the steel fire-box plates, tube plates, etc., are flanged by hydraulic presses. Here are to be seen three very fine punching and flanging presses, with rams up to 30 inches diameter, working at a pressure of 2000 pounds per square inch, and capable of flanging, in one operation, steel fire-box plates measuring 6 feet 6 inches by 4 feet.

In connection with the boiler and flanging shops is a smithy, containing sixty smith's hearths. There all the forging work required in the boiler and other departments is carried out. There are in this shop three steam hammers of 7, 15, and 30 cwts., respectively, and also a steam welding machine and a saw for cutting hot metal.

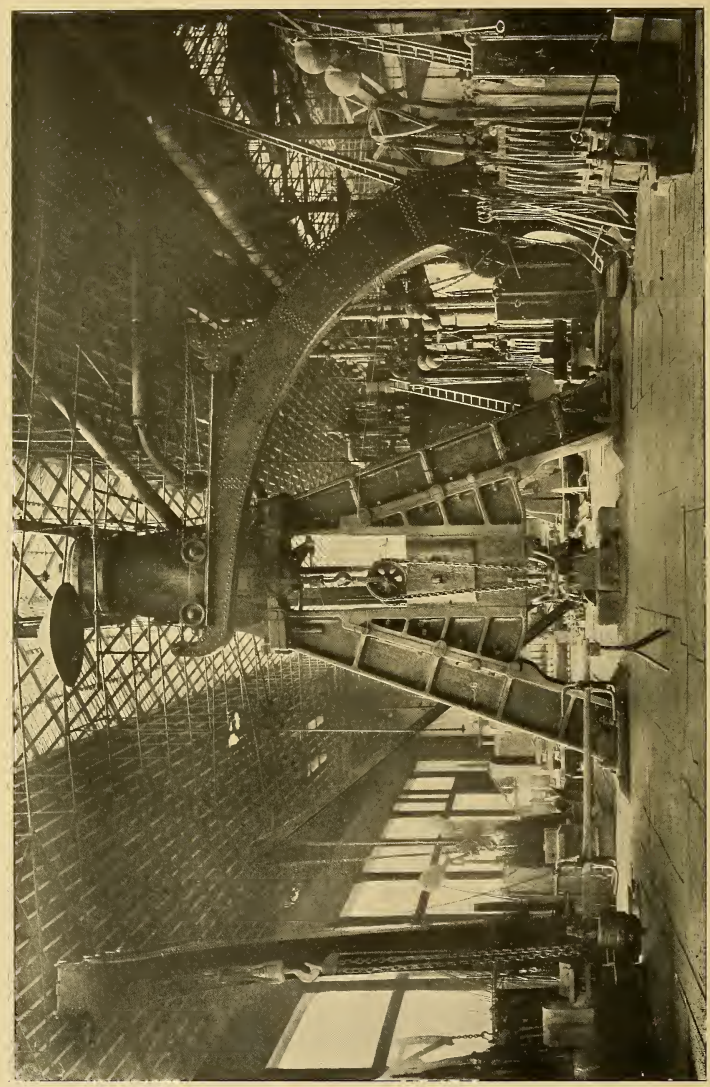
The plate store adjoining the flanging shop is used for storing all the necessary plates, round and square bar iron, and other materials in a commercial form, required for various purposes. An electric overhead crane is fitted for handling the material.

In the ordinary course of events, as a glance at the plan of the works will show, the erecting shops would be considered as following upon the plate store on the round of inspection; but the more interesting plan is to retrace one's steps, and, by remaining outside the shops and passing along the yard between the two sets of buildings, enter the steel foundry, and then continue in the same direction as before, finally reaching the erecting shops, after having witnessed further manufacturing processes from the raw material, a course which will enable the visitor to better appreciate the various operations which he will see in the erecting shops.

The power station, containing all the machinery for electrically lighting the steel works and supplying the power for driving the machinery has first to be seen, however. This plant consists of four sets of high-speed vertical engines built by Messrs. Belliss & Morcom, Ltd., of Birmingham, coupled to dynamos built at the Crewe Works. Steam is supplied by four Babcock & Wilcox boilers. On the way to the steel foundry other sets of boilers are passed. These furnish steam for the various engines throughout the works, and are forty-one in number, twenty-five being of the locomotive type and sixteen of the Lancashire type, the latter being 7 feet in diameter and 30 feet long. All these were made at the works, and are constructed entirely of steel.

Near these boilers are to be seen a large number of galvanised iron troughs used for carrying the water on the permanent way, in connection with the Ramsbottom water pick-up apparatus so extensively used on the London & North-Western Railway. The material used for these is steel ⅛ inch thick. These troughs are made up in 10-foot lengths and sent out in lots consisting of three lengths riveted together, the remainder being connected up on arrival at the required spot.

The steel foundry is one of the most important sections of the Crewe Works. Mr. Webb had given a very considerable amount of attention to the possibilities of using steel castings, and thus effected a remarkable saving in the cost of manufacturing numerous articles which were formerly produced by the more expensive method of forging. The steel foun-



THE LARGE STEAM HAMMER AND CRANE

dry plant consists of two 10-ton steel melting furnaces fitted with suitable hydraulic machinery for manipulating the ladles, various travelling and jib cranes, also revolving hydraulic tables for casting wheels, and axle-box moulding and other machines. Many articles formerly made of cast iron are now made of cast steel, including such important parts as wheels, motion plates, brackets, axle boxes, and brake hangers.

The next department to be visited is that known as the forge. The first objects which meet the eye on entering this shop are numerous piles of metal, which, on closer inspection, prove to be composed of shearings and cuttings from various articles of manufacture, such as rail ends, odd pieces of iron, old horseshoes, many of which are forwarded to Crewe when done with from various parts of the company's system, and a host of other odds and ends. Each pile represents an accurately weighed quantity of material, and the whole is converted into billets, which are eventually rolled into merchant bars of various sections and sizes.

A little further on the rolling of spring steel may be witnessed, and immediately afterwards the method employed in the manufacture of fish plates for the permanent way is to be seen. First the heated ingot is passed through rolls and reduced into a long bar of fish-plate section. This bar is then passed along to a circular saw and there cut into exact lengths required for the fish plates. After this the plates are dealt with by a trimming machine, which removes all burrs and ragged edges from the ends, and from there they are passed to a combination machine, one side of which punches the four bolt holes in the plates while the other side of the machine straightens them. After this the plates are stacked up ready for use.

The various operations involved in the manufacture of tires, including all the different stages, can be followed a few minutes later. The ingots from which the tires are made are of conical formation, and, after having been removed from the moulds, are reheated in gas furnaces. The first one to be dealt with is then placed upon the table of the hydraulic press, the ram of which compresses the ingot into a circular mass with flattened sides, resembling somewhat a large cheese, the thickness ranging from 8 to 9 inches. The next step is to punch a hole through the centre, and this is done with a tapered punch with one stroke of the ram.

The hot metal is now similar in shape to a ring or collar, and has next to undergo the process of "roughing out" or the first stage of shaping. This is carried out under a 5-ton steam hammer, which forms part of the equipment of this department. Further reheating is, however, necessary, and a visit to the gas furnaces is, therefore, again undertaken. A number of the ring-shaped masses are stacked in the furnaces after the fashion of a honeycomb, and when heated to the proper temperature they are withdrawn in pairs and are placed upon the block of the 5-ton hammer, being hung on suitable horns which are provided, one on either side of the block.

The hammer head is fitted with suitable dies for producing the flange and tread of the tire, and the work is slowly rotated during the interval between blows of the hammer by a man provided with a long fork for the purpose. The resulting rough tire is once more reheated and then conveyed to the tire mill, where it is completed, so far as the forge department is concerned. That portion of this process which is performed by the steam hammer is known as "becking out" a tire. Each tire is stamped with certain letters and marks for subsequent identification. The average output of tires of all kinds is 4149 tons per annum.

The large hydraulic press shown on page 400 is worthy of attention. It was erected in 1899, and is used principally for drawing down the steel ingots required for making crank and straight axles and other work of similarly heavy description. This press is provided with a gauge, which is fixed to the side facing the operator, who, whilst manipulating the controlling lever can, by watching the movements of the pointer, —which, it is hardly necessary to add,

is actuated by the plunger,—ascertain beyond any doubt the right moment at which he should release the latter for the next stroke. By this means there is no difficulty in maintaining the same thickness throughout the entire length of the metal which is being reduced.

Electrically operated "turn-over" gear is provided for use in connection with this press, and this greatly facilitates the handling of large masses of metal and results in a considerable saving of time, thus enabling more work to be done in the same heat than was possible when all the turning movements had to be made by hand. The maximum pressure obtained from this press is 2000 tons.

The plate mill, which is next visited, has all the necessary apparatus for rolling engine frames, boiler plates, etc. The rolls of this mill are 24 inches in diameter. A pair of vertical reversing engines supply the power. Steel plates for stationary boilers have been rolled in the mill, 24 feet long by 4 feet 9 inches wide and ⅜ inch thick, and also plates for locomotive fire-boxes 17 feet long, 6 feet wide and ½ inch thick.

All the axles required for the carriage and waggon departments are rolled in another mill, similar in size to the plate mill. They are rolled with the required taper, small in the middle and tapering out to a large diameter at the ends.

The forge department is fitted with two hydraulic forging presses; four vertical steam hammers, ranging from 8 tons to 50 cwts.; one plate and axle mill, with four sets of rolls; a tire mill capable of rolling tires up to 8 feet 9 inches in diameter; hydraulic and hand-power cranes, lifts and hoists, besides various punching and shearing machines and two 7-foot circular saws for hot metal. These saws are driven by special engines, and their peripherical speed is 13,000 feet per minute. They will cut through a 9-inch axle in less than half a minute

Nos. 5, 6, 7 and 8 erecting shops are by this time reached, and here locomotive engines in all possible stages of repair are to be seen. No new construction is undertaken in Nos. 5 and 6 shops, which are devoted to repair work only, chiefly of goods engines, each shop being fitted with four 25-ton travelling cranes. With the exception of No. 8, all these erecting shops are provided with floor traversers for bringing engines in and taking them out again when completed.

No. 7 is used as a boiler mounting shop, the boilers being there received from the boiler shop and fitted with their lagging, tubes, and the various brass mountings. They are all subjected to hydraulic and steam tests in this shop before being sent on further. The maximum working locomotive boiler pressure is 200 pounds per square inch. This shop is fitted with four 20-ton electrical travelling cranes.

No. 8 erecting shop is principally devoted to the construction of new locomotives, and is well equipped with the usual tools and appliances necessary for the requirements of this work. The other plant consists of a frame-fitting machine upon which the engine frames are automatically fixed parallel and true to each other, and then all the connecting pieces, such as cylinders, motion plate, and foot plate, are bolted and riveted in position, all holes required being drilled by two portable electric drilling machines-

Some very commodious and well-lighted shops are being erected at the present time. One of these is already completed, and is used as an additional erecting shop, being known for the present as the New Shop. Upon entering this building it is at once apparent that every provision has been made for the comfort of the workmen and the expeditious handling of the work.

There are one or two special points about this shop which are worthy of mention. In accordance with customary practice, glass is largely used in the construction of the roof, and in order that the minimum amount of risk may be incurred in the event of breakages, cross wires are incorporated in the glass itself, so that, should any portion of it get broken, the pieces are held by the wire, and are prevented from falling into the shop below.

The new shops are distant a few min-

utes' walk from the other "Steel Works" buildings; but, with commendable foresight, they have been erected strictly in line with the latter, so that when the time arrives,—as it assuredly will,—for the intervening space to be covered with additional shops, they can be connected up to the existing buildings, and will then form one continuous structure.

The yard is at present used for storing wheels mounted on axles, and also as an assembly ground for engines awaiting repairs. Alongside the new erecting shop a machine shop is fast being prepared, and when this is completed a large amount of work which is at present carried out at the Old Works will be done there.

All the clay that is excavated, as these new works are proceeded with, is taken to the adjacent brick yard and is used up in the manufacture of bricks which are employed on the various "locomotive" buildings throughout the line.

It should be mentioned that the designs for the new shops, and indeed all Locomotive Department buildings, are prepared at Crewe, and the drawings are made in the drawing office there.

From the new shops to the iron foundry is but a short distance. A great quantity of work is there done by moulding machines, and large numbers of plated patterns are used for the smaller articles.

There are seven cupolas, with capacities ranging from 2 to 30 cwts. The pig-iron and coke for the larger ones are raised by hydraulic hoist bodily in the waggons in which they arrive at the works to a platform about level with the cupola mouth. Two 10-ton electric travelling-cranes, with numerous hydraulic and hand-cranes, wheel, cylinder and other moulding machines, grinding mills, etc., complete the equipment. Adjoining the main building there is a smaller foundry, which is devoted especially to the casting of the large numbers of rail chairs required for the permanent way. The larger building is 462 feet long by 121 feet wide.

The pattern shop and stores adjoin the iron foundry, and are, therefore, very convenient for passing patterns to and fro. All the patterns are arranged in tiers, each section being neatly marked. Small square boards are fixed to each locker, painted black, with white raised letters and beading, the former indicating the character of the patterns within, such as "7-foot compounds, 6 and 8 wheels," "Metropolitan type side tank and 5-foot 6-inch ditto," etc. Thus it is easily ascertainable where the various patterns are to be found.

The concluding portion of this article will appear in the October number.

ELECTRIC METERS

THEIR RELATION TO THE EARNING POWER OF ELECTRIC LIGHT COMPANIES

By Caryl D. Haskins

THE efficiency of generating apparatus and distributing devices and systems, the efficiency of engines, boilers, or other prime movers, and even the price of coal are relatively insignificant factors individually in the earning power of an electric light property as compared with the meters which are used upon the system.

The intelligent selection of the best meter for the conditions to be met, and the intelligent upkeep and supervision of these meters after their installation, in a large measure determine whether the illuminating property will or will not yield adequate earnings for the stockholders.

The average electric light system today delivers to its customers not less than 10 per cent. more energy than those customers pay for. This loss of 10 per cent. of the just revenue is due to three causes:—

1.—The continued prevalence of a certain considerable percentage of contract customers having no meters.

2.—The use of inefficient, low-grade, or obsolete meters.

3.—The failure to test, inspect, and maintain the meters which are in service.

The assumption that a meter which, when just purchased, shows excellent accuracy from light load to full load, will remain and continue to show similar results in service is a fallacy. A recording meter is a low-powered and delicate piece of apparatus at best, and its accuracy will remain permanent almost in direct proportion to the relative amount of power or turning force which the meter possesses. It will be appreciated by all that a device having very little turning power may, nevertheless, run with perfect accuracy and freedom when entirely clean and unworn in any of its parts.

A meter to be permanently accurate must not only show good accuracy from a very light load, say 2 to 5 per cent. of its rated capacity, up to a reasonable overload, say 20 to 50 per cent. of its rated capacity, but must also under measurement show a high turning moment or torque.

As a general thing a fair idea of the relative torque or turning moment of a meter can be obtained by noting the number and sizes of drag magnets applied to the damping disc. The larger and more numerous these magnets are, generally speaking, the more considerable the torque; but this evidence cannot be relied upon wholly, because magnets vary widely in strength; consequently more positive means should be resorted to for measuring the torque.

A popular misconception has prevailed to the effect that there is advantage in using only one or two sizes of meter, the idea being that a less total number of meters will have to be purchased if only two or three sizes are used, since a smaller reserve stock will be required. The only economy achieved by this policy is the necessity of purchasing a somewhat less number of meters for stock. This may affect the expenditure of the company for meters to the extent of 5 or 10 per cent. But 5 or 10 per cent. of the annual expenditures of a lighting company for meters is a sum utterly insignificant as compared with a loss of even 1 per cent. on the revenue. As in the case of meters of low turning moment or torque, so, too, large meters may initially show remarkable accuracy on small loads;

but the turning moment or torque of every known form of motor type, recording watt-hour meter decreases in direct proportion to the load. Consequently a meter which, for example, has a torque of 80 mm. gms. at full load, and is of 25 ampères capacity, will at one lamp (½ ampère) have a torque or turning moment of one-fiftieth of 80 mm. gms., or 1.6 mm. gms.

However well this meter may perform at this load when new, it cannot be expected to perform with equal accuracy after a year or two of use, as compared with a meter having 80 mm. gms. at full load and of a capacity of 10 ampères, because the 10-ampère meter at one lamp will have a torque of one-twentieth of 80, or 4 mm. gms. Hence, lighting companies should always use the smallest meters which they can use with safety. This may be detrimental to the immediate interests of manufacturing companies who secure somewhat higher prices and therefore larger gross sales in connection with the sale of large meters than small, but it is distinctly to the advantage of the illuminating company. It is better to carry 10 or 15 per cent. more meters in stock and to occasionally lose a meter from a burnout due to overload,—a very rare occurrence in modern meters,—than it is to put in meters larger than are required.

Illuminating companies should also be exceedingly careful in their investigation of meters which appear to have extreme overload capacities. For example, a meter having the best of accuracy at 100 per cent. overload may very fairly be considered as being a meter which is really rated lower than its actual size. If, for example, a meter is rated at 15 ampères and shows the best of accuracy at 30 ampères, it is debatable whether this meter should not in reality be rated at say 20 or 25 ampères. This means that the light load will suffer for the reasons given above.

The safest way in studying permanent accuracy in relation to light load is to reduce the calculation to mm. gms. torque at one-twentieth load, or 5 per cent. of the meter's rated capacity. Long experience has taught that sustained meter accuracy over a period of years cannot, and should not, be expected at loads of less than one-twentieth of a meter's rating. Below this, fair approximations only may be achieved, dependent upon the construction, and largely upon the torque of the meter. It may be said generally that loads on which a meter operates at less than, say, 3 mm. gms. torque will be loads upon which the meter will not permanently render the highest accuracy.

Thoughtful central station managements will readily appreciate from these statements the grave effect upon revenue which may result from a slight initial mistake in the selection of meters.

Up to this point only questions pertinent to non-inductive loads and the accuracy of the meter thereon have been dealt with. It must be remembered, however, that there are other conditions besides those already cited which must be accurately dealt with by the meter. Inductive loads are common already and are becoming more so. Fortunately, the accuracy of a meter on inductive loads changes little if any in service. In other words, accuracy on inductive loads will remain practically unchanged in relation to the accuracy on non-inductive loads.

Meters not infrequently err initially on arc lamp and fan loads, and, therefore, no meter should be used by a central station which fails to show a high degree of accuracy under such conditions. Inductive devices frequently form a very large proportion of the whole load, especially during the summer months, and very serious impairments of revenue may result from the use of a meter which may be entirely accurate under non-inductive loads. In some cases under these conditions meters may operate too fast, leading to a dispute with the customer, a test and demonstration of excessive record, and a rebate extending back possibly for months and affecting bills which may very well have been recorded, not upon inductive loads, but upon non-inductive loads, thus resulting in a rebate many times in excess of the actual over record,

and thus seriously impairing the gross revenue of the company.

Lighting companies should, furthermore, weigh with great care the question of using meters sealed prior to shipment. Meters which are sealed and which must be returned to the manufacturer for recalibration, repair or adjustment, menace the revenue of the company as well as its expenditures. They menace the revenue because the temptation to leave such meters in service long after they cease to record with high accuracy on light loads is almost irresistibly strong. No central station likes to remove a meter from the premises of a customer and install another. It increases expenses for labour and it shakes the confidence of the customer. Consequently, rather than take down a meter which is inaccurate and return it to the manufacturer for repairs, it is often left to operate month after month on a basis which loses to the illuminating company a considerable percentage of its just revenue.

Such a meter, when finally removed and returned to the manufacturer, even though it be repaired under a guarantee and therefore at no cost to the lighting company, must be out of stock for a considerable time, so that instead of becoming available for immediate reinstallation within forty-eight hours of the time of its removal, as it would be in case repairs were executed locally, it may be out of hand for weeks or even months, thus necessitating carrying a materially heavier stock in the local store room, although, as a matter of fact, the fault for which the meter was removed might in all probability have been repaired with ease and dispatch on the premises of the customer without removing the meter from the wall and without creating suspicion.

The wear of bearings in meters is the most common and prolific source of revenue-impairing trouble incident to recording meters. It must be borne in mind that friction in a meter is inevitable and that that form of bearing which shows the least friction initially need by no means be, and seldom is, the best bearing for a long period. The most efficient form of bearing yet devised for recording meters consists of a cup-shaped jewel of sapphire as the stationary member and a pointed shaft end or pivot, the point of which should be of the hardest and toughest steel, possessing the highest polish and having a section of substantially a hemisphere.

Such bearings have in the past given a great amount of trouble when used in connection with meter mechanisms, which from principle or construction were obliged to carry rotating elements of extreme weight. Such bearings also have proved highly fallible when used in connection with meters of very low torque. In the first instance wear of the sapphire and pivot have resulted after a year or more of use, necessitating the renewal of both jewel and pivot. In the second instance in meters of low turning moment a general slowing up of the meter from friction results, at least in a considerable measure, from the accumulation of foreign matter in the jewel cup, which would be unimportant in connection with a meter of high torque, but which may materially reduce the speed of a device of low turning moment.

Side or lateral friction is likely to be more serious and detrimental than vertical pivot friction, since it is applied to a larger diameter of the moving part. Hence the accurate level of meters is of importance, and meters should be especially selected with a view to a maximum freedom from bearing surfaces making contact with the rotor laterally.

Much of success or failure depends upon the construction of that portion of the meter known as the recording train or dial. It is in this portion of the meter mechanism that friction frequently goes up in a rapid ratio, as the age of the meter increases. This is due to dirt, wear, and bad construction. A badly cut or rough worm not infrequently cuts and destroys the shape of the teeth of the worm wheel, in some cases multiplying the friction between worm wheel and worm by a large amount. The use of iron pinions with resulting rust is a prevalent cause of trouble, and it must always be remembered that substantially no recording

train can be run all of the way around on all wheels to prove the accuracy of cutting of the pinions and teeth Consequently, unless recording trains are cut and finished with the utmost nicety and care, great friction may suddenly develop after the meter has run several million revolutions, because even at this point the last or highest wheel will not have made a complete revolution, and may at any time present an imperfect tooth with consequent evil results. The worm, pivot, and wheel construction of recording mechanisms should be the subject of special analytical examination.

In connection with recording train difficulties the importance of high turning moment or torque will be appreciated. The check due to an imperfect tooth in a recording dial is severe, but temporary, and a meter having a high turning moment may very well run over and past an imperfect tooth which would stop a meter of lower power. This is true, whether the temporary check be due to the imperfect wheel, or to dirt, or rust, or other friction producer.

The effect of external temperatures upon meters should be watched with the greatest care. Almost all central station systems have a large number of meters installed at points where they are exposed to changes of temperature ranging from almost zero degrees F. to 100 degress F. In numerous instances these changes of temperature may affect the revenue of the company.

As a last word of warning, it should be remembered that meters rarely err by over-record. Ninety-nine times out of one hundred such errors as occur are errors slow. Substantially every meter in service under-records at some load, and the accumulation of such errors throughout an entire system is always an increasing factor, save in the face of constant vigilance.

The lost revenue which could be saved with the meter art as it now stands might well suffice to pay dividends on the common stock of many corporations which to-day pay none, and yet have sufficient surplus to create a substantial annual sinking fund.

THE LARGE GAS ENGINE IN GREAT BRITAIN

BLAST FURNACE GAS AS A FACTOR IN ITS DEVELOPMENT

By William H. Booth

THE gas engine as a prime mover dates practically from the year 1876, when the free-piston engine of Otto and Langen began to sell readily, and a crowd of small gas motors followed closely upon its heels. This is only about a generation ago, and in this period the gas engine has made steady and continuous advance, and has arrived at the state of being properly classed as a large-power engine. A certain delay in progress was, perhaps, noticeable at the stage when the engine became uncomfortably large to be started by one man. This gave rise to self-starting devices, some of which depended upon the storage of compressed air, which has many advantages and few disadvantages. With very large engines, however, a small starting engine can be employed, as is done in the case of the steam engine. Generally the preliminary difficulties of the large engine have been overcome, and no one would now seriously advance these difficulties in respect of any present-day proposition to employ a large gas engine in stationary work, though the large marine gas engine is still to come.

The gas engine is not essentially different from the steam engine, but it has assumed a somewhat different appearance because of the abolition of the crosshead and piston-rod and the direct attachment of the connecting-rod to the piston. This has made the gas engine shorter than the steam engine, and the intensity of the explosions has caused to be evolved a machine of very stiff parts. In a double-acting steam engine the stresses in the crankshaft are always in one direction. In the gas engine, not only does the pressure act but one way upon the crank, but the work of compression exerts a load upon it in a contrary direction, and the crankshaft of the gas engine must thus be made abnormally strong, as compared with the shaft of a double-acting steam engine of equal power.

High speed of revolution and a short stroke add to the effect; but, apart from this, the gas engine is simply a piston engine which is worked by the pressure of a gas. It differs, however, from the steam engine in that the working fluid is heated in the cylinder itself by the combustion of gas in combination with the working fluid. The gas engine is really a hot air engine, the air being drawn into the cylinder, and serving not only as the recipient of the heat of the fuel, but also affording the oxygen to combine with the fuel.

Improved methods of manufacture, speed, experience, and high compression have each done their part in securing present-day results; but the gas engine is essentially a poor heat engine in itself. True, there are no boiler losses to detract from total efficiency, as in the steam engine; but the inability of the cylinder metal and of the piston to work at the high temperature which is produced in the cylinder of the gas engine makes it necessary to envelop the cylinder in a water jacket so as to keep the metal at a safe working temperature.

As an accessory to a heat engine the water jacket represents most unsound practice, but there is at present no prospect of this being abolished. The water jacket has a much greater effect upon a small than upon a large cylinder, because cylinder volumes increase faster than their internal surfaces. With small engines the influence of the jacket is considerable, and the jacket abstracts a

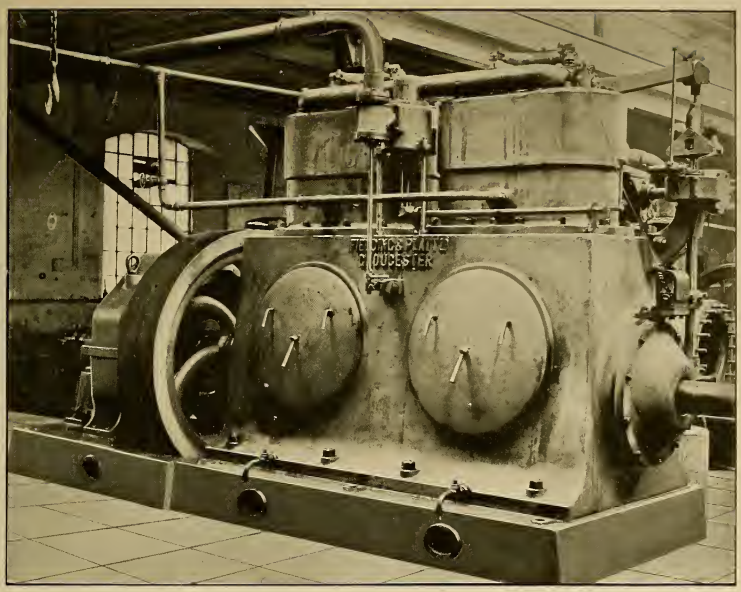


FIG. I.—A FOUR-CYLINDER VERTICAL GAS ENGINE MADE BY MESSRS. FIELDING & PLATT, LTD., GLOUCESTER

larger proportion of the heat of the charge. All the early gas engines were worked by hydrogenous gas, usually some town's illuminating gas carrying a large proportion of hydrogen. It is well known that hydrogen ignites at a very much lower temperature than carbonic oxide. In small engines the hydrogen gases did not, perhaps, produce too many premature explosions due to ignition during the compression stroke, for the jacket kept the cylinder cool ; but in large engines there is a tendency to greater temperatures, and gases rich in hydrogen are inadmissible for such engines, which work better with the poorer producer gas or with the lean gas of the blast furnace. Gas rich in hydrogen cannot be employed with high compression, for there is too great a risk of premature explosion, and this is a far more serious matter than the same occurrence in a small engine.

Probably the greatest impetus has been given to the large gas engine by the Thwaite system of blast furnace gas utilisation. It was only in 1896 that the writer made the first public and independent test of the first gas engine ever worked with blast furnace gas. Since that time the use of blast furnace gas in gas engines has become comparatively common. More has been done upon the Continent of Europe than in Great Britain, but much more would have been done had not the Continental engineers got hold of the curious and erroneous idea that blast furnace gas could be used in the gas engine with all its load of grit and dust without cleansing. Though progress has been slower in Great Britain, no British engineer has proposed such a folly as this, and the British cleansing method of Thwaite, the originator of the whole system, has now received universal recognition as an essential part of the utilisation of this gas.

If the gas furnace were used to its full

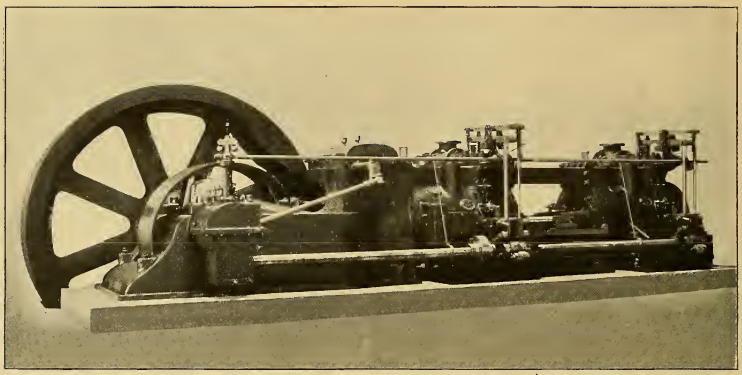


FIG. 2.—A 500 B. H. P. TWO-CYLINDER TANDEM GAS ENGINE BUILT BY THE PREMIER GAS ENGINE CO., SANDIACRE. THIS ENGINE HAS A THIRD OR SCAVENGING CYLINDER

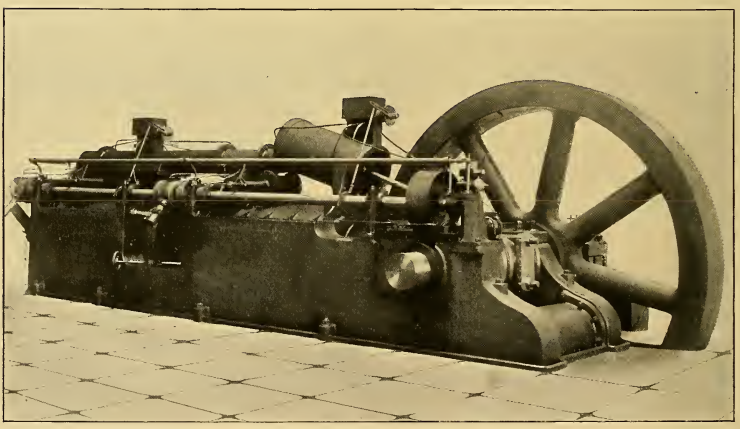


FIG. 3.—A NEW TYPE OF PREMIER ENGINE, IN THIS THE SCAVENGING CYLINDER IS PLACED ABOVE THE FORWARD CYLINDER, AT AN ANGLE

capacity it would provide power in immense quantities, and this could be electrically transmitted by high-tension lines to centres of large industry or population. Transmission can be effected only electrically; hence the demand which is growing up for large gas engines that will run steadily enough to drive alternating-current machines.

A list of any maker of gas engines will illustrate the large and varied field in which gas engines are now used. This covers all kind of trade and industries, from water pumping to electric lighting work. Messrs. Crossley Brothers, Ltd., of Manchester, for example, publish a list of engines of over 50 H. P., including many of 110 H. P. effective, some of 190 H. P., a considerable number of 160, and others of 210

and 450 H. P. Such engines may still be called large, but of late the power of gas engines has very much increased. One of the Crossley 100 H. P. engines is guaranteed to run with a mechanical efficiency of not less than 85 per cent. with producer gas, consumes not more than one pound of fuel per effective horse-power-hour, and is governed within a 3 per cent. speed variation between no load and full load. These engines are usually provided with a compressed air starter driven by a small engine and provided with a reservoir. Ignition is effected by means of porcelain tubes in duplicate, and the explosive mixture is admitted to these by timing valves which safeguard the engine, so far as can be, against too early explosions.

A double-cylinder engine capable of developing 610 B. H. P. with coal gas and 460 B. H. P. with producer gas will have cylinders 28 inches by 36 inches, will run at 150 revolutions per minute, and occupy a floor space 27 feet by 16 feet. The fly-wheel will measure 9 feet in diameter, with a face of 27 inches. The engine weighs sixty tons.

Though not of large cylinder dimensions, the engine of Fielding & Platt, Fig. 1, is interesting as an example of an engine of fair size and of the vertical type. It has four cylinders, and, therefore, will give great cyclical regularity, and will promptly meet sudden demands for power. Graduated governing is employed, and wear is even owing to the vertical position. These vertical engines bear a very strong resemblance to the vertical high-speed steam engine, and the makers will build them up to 750 B. H. P.

One of the advantages of the four-cylinder engine is that it can be started by means of compressed air in one cylinder only, and the air can be shut off as soon as the other cylinders fire their first charge, the cylinder that has been employed for starting purposes being then also put into action. Starting air is stored at a pressure of 100 pounds per square inch, a small compressor maintaining this pressure.

In Fig. 2 is shown a 500 H. P. tandem engine built by the Premier Gas Engine Company, of Sandiacre. These engines have a third, or scavenging, cylinder, which acts, with its piston, as a crosshead and guide, the back piston being connected to the crosshead by side rods. The pistons are water-cooled.

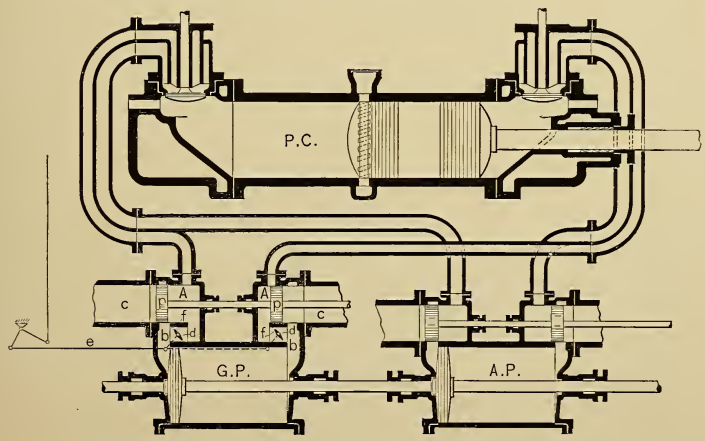


FIG. 4.—ARRANGEMENT OF ENGINE AND PUMPS OF THE KÖRTING GAS ENGINE AS MADE BY MESSRS. FRASER & CHALMERS, LTD., LONDON

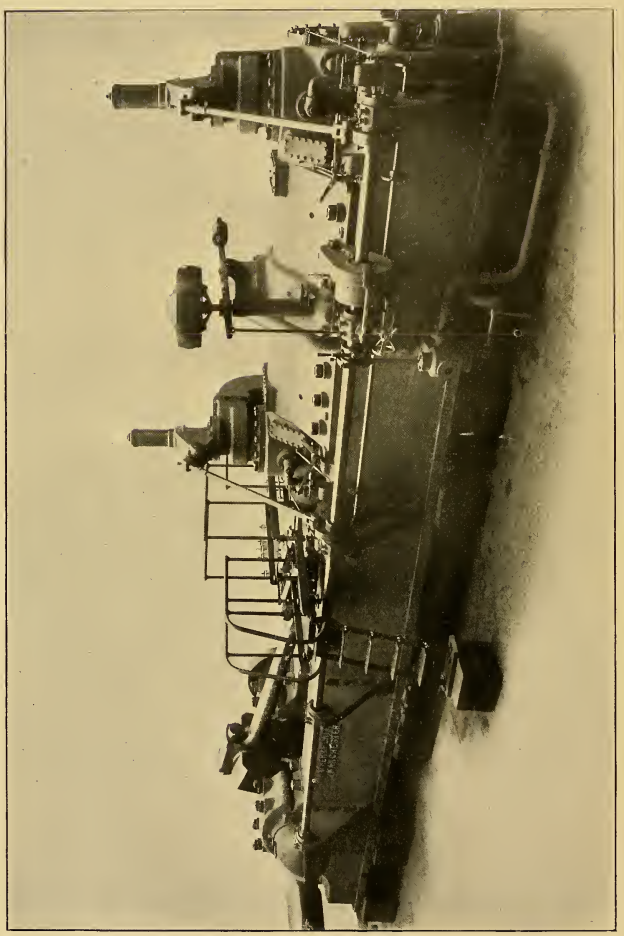


FIG. 6.—A 700-H. P. KÖRTING ENGINE BUILT BY MESSRS. MATHER & PLATT, LTD., MANCHESTER

When tested at 489 I. H. P. this 500 H. P. engine showed an average effective pressure of 108.25 pounds, a brake H. P. of 368, and a thermal efficiency of 30.28 per cent. The gas was Mond gas, and was analysed to contain 143.8 B. T. U. per cubic foot. It contained 27.8 per cent. of hydrogen, as well as 2.2 per cent. of marsh gas. With gas of this type, pre-ignition must be guarded against by effective cooling, and no doubt the powerful scavenging effect of the large air piston assists to eliminate the causes of pre-ignition. Compression is to about 140 pounds gauge pressure, and the minimum pressure of explosion is about 330 with Mond gas.

A new type of Premier engine is that of Fig. 3, which is built in sizes from 300 to 1000 I. H. P. The scavenging cylinder is placed above the forward cylinder at an angle, and its piston is driven by a rod connected to the head of the main connecting-rod. Four-cylinder engines of this type will be built up to 2000 I. H. P., perfectly suitable for driving alternators.

In the Körting gas engine, of which several illustrations are given, of the type built by Mather & Platt, and also by Fraser & Chalmers, we have a resuscitation of an old idea which failed of commercial success, like many good things that came before their time. The Clerk gas engine employed separate compression cylinders, and thereby secured a working stroke at each revolution of the engine. The Clerk engine secured what Atkinson also aimed at, a ratio of expansion greater than could be

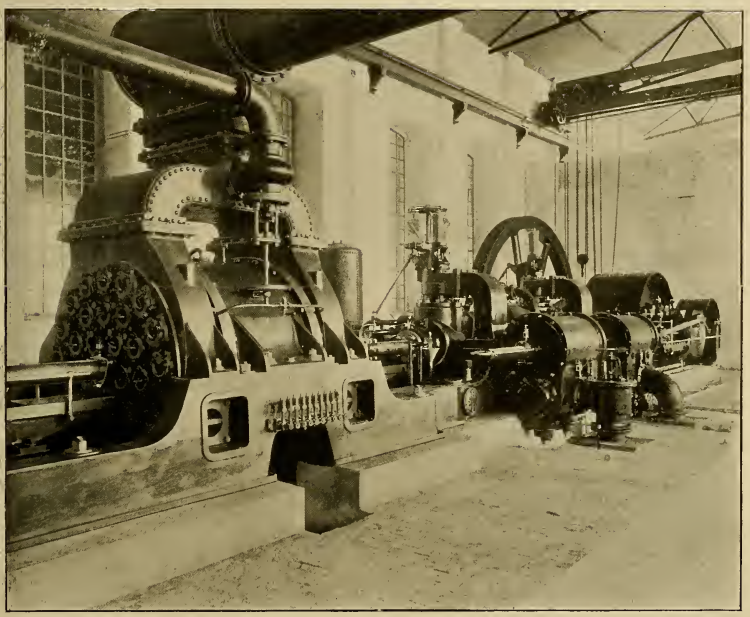


FIG. 5.—A 500 BRAKE H. P. KÖRTING GAS ENGINE WITH BLOWING CYLINDERS DIRECTLY COUPLED TO TAIL END. THE ENGINE IS RUNNING WITH BLAST FURNACE GAS. DIAMETER OF CYLINDER, 25 INCHES; STROKE, 43 INCHES; SPEED, 100 REVOLUTIONS PER MINUTE. BUILT BY MESSRS. FRASER & CHALMERS, LTD., LONDON.

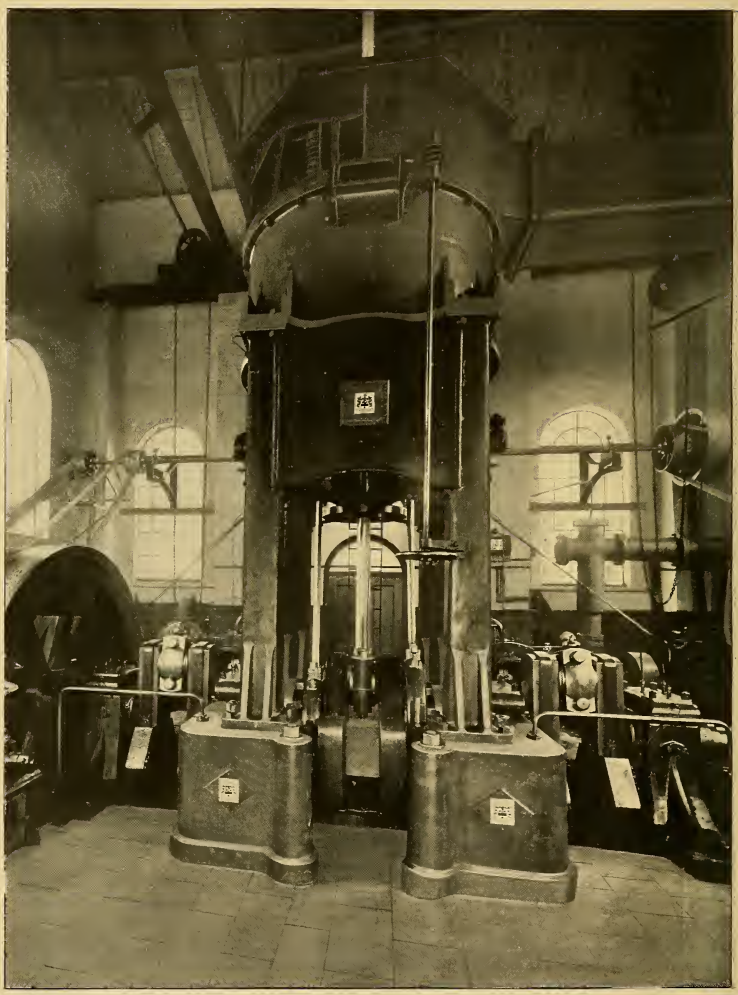


FIG. 7.—THWAITE'S GAS BLOWING ENGINE AT CLAYCROSS IRONWORKS, NEAR CHESTERFIELD. HERE TWO HORIZONTAL POWER CYLINDERS DRIVE A CENTRAL VERTICAL AIR BLAST CYLINDER

got from an ordinary engine. The Körting engine which is made in Great Britain by the above firms is the Clerk engine again in principle. It is, however, double-acting, and has a water-cooled gland for its piston rod. Gas and air, compressed each by its own special pump, are admitted to the working cylinder by mushroom valves, and exhaust takes place at the middle of the cylinder through ports which are uncovered by each end of the long piston in turn.

Thus, as the pressure falls by exhaust, the inlet valve is opened and the fresh charge drives the remainder of the exhausted charge out of the middle ports until these are again covered by the returning piston. Shortly after this the pumps arrive at their dead points, the inlet is closed, the fresh charge is compressed and fired. There is thus an explosion at each end of the cylinder at every revolution. This is the Clerk cycle.

Taking the gas pump which, in the diagram Fig 4, is marked *G.P.*, it will be observed that gas is drawn in at the passages *bb* from the gas supply *cc* and forced on the return stroke of the gas piston, which is double-acting, through mushroom valves into the engine cylinder together with air forced by a similar pump marked *A.P.*

Piston valves *pp* admit and shut off the gas charge and throttle valves *dd* serve to regulate the actual volume of gas sent forward to the cylinder. The air pump has no regulator, the full amount always going forward and acting partly to support combustion and partly as a scavenger.

The advantages claimed for the Körting engine are that it works on the double-acting, two-cylinder system, and that the combustion chamber where the greatest amount of heat is developed lies outside of the power cylinder proper. The temperature of the cylinder walls is kept low. The exhaust slots are in the middle of the cylinder, and the burnt charge is exhausted alternately from either side. The mixture of the charge is effected by the pumps, and does not take place till the gas and air meet at the inlet valve, and there is no storage of combustible mixture at all. There are no exhaust valves exposed to the high heat of the exhaust gases.

Moderate air pressure only is necessary to start, the pressure being always lower than that of the compressed charge. As there is an impulse every stroke, the weight of the fly-wheels for a given cyclical variation is lower than with other engines.

Single-cylinder engines are built in units from 400 B. H. P. to 1500 B. H. P., and by duplicating these powers in a twin cylinder, engines from 800 B. H. P. to 3000 B. H. P. are obtained. With poor gas of blast-furnace quality, containing little hydrogen, compression can be carried to a high degree, 150 to 180 pounds.

A curious feature of all gas engines, and one that is particularly noticeable in those of large sizes, is the ease with which they can be started up, as compared with large steam engines. A large steam engine must first be heated up to the temperature of the steam or this fluid will condense in great volume and will produce much water until the cylinder metal has become hot. The specific heat of iron is about 0.11, so that the condensation of one pound of steam will serve to heat about fifty pounds of iron to the exhaust temperature of, say, 212° F.

With gas about 70 per cent. of the heat are thrown away, either to the jacket or in the exhaust, and when a gas engine is started, this waste heat is less than usual, for some of it goes to warm up the engine. The working of a gas engine in this sense is very crude and unscientific. The steam engine would occupy the same position if it were placed in the furnace of the steam generator. It might then be necessary to jacket the cylinder with water to keep it cool enough to work.

The gas engine is more efficient than the steam engine only because it starts so much nearer to the beginning of the heat cycle. All the heat generated passes through the engine, and we use as much as we dare use consistently with the possibilities of our materials of construction. In the steam engine we as-

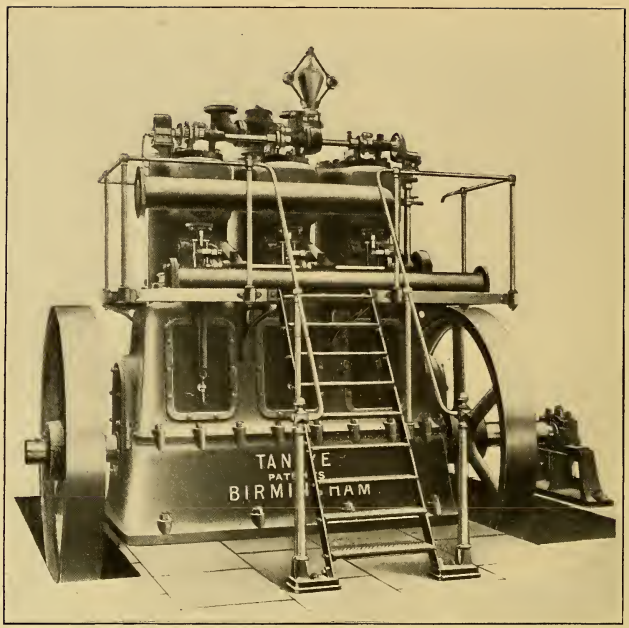


FIG. 8.—A 200 H. P. THREE-CYLINDER VERTICAL GAS ENGINE, MADE BY MESSRS. TANGYES, LTD., BIRMINGHAM

once throw at least a fourth of the fuel heat up the chimney, and the remainder we allow to fall to a lower potential plane, and in place of using it at the furnace temperature of 2500° F., we employ it at only 350° or 550° at most.

It is becoming looked upon also as something of an error to produce indicator diagrams from a gas engine which resemble the diagram from a steam engine in having a vertical "admission" line. This vertical line tells us that full pressure and temperature are admitted upon the piston, while this is standing still, on the dead point. In this case the heat of the gas explosion is all going into heating of the piston and cylinder. If, however, the admission line, or, as it should be called, the explosion line, is allowed to be late, the piston will be in motion, and the heat of the burning gas will then be economically converted into work by the moving piston. The vertical explosion line is a very doubtful virtue indeed in the gas engine, and though further trial may be necessary to determine the actual facts, such trials are worth making in order to demonstrate the point. Maximum pressure at the dead point implies, after all, a braking effect on the large crank neck and pin when no rotative effect is being secured. The gas engine is thus differentiating itself from the steam engine in various technical forms, though it retains fully the general form which seems to be inseparable from all fluid-pressure piston engines. As with steam, the problem of the gas engine is to recover, as work, as much as possible of the heat capacity of the fuel employed. With steam engines very little use has been made of the wasted heat. It has appeared cheaper to condense the steam

and gain the power of the vacuum. With gas there is no condensation, and in places where large gas engines are likely to be employed there is often a field for the use of waste heat, as in factory warming and the heating of water for dyeing and other trade purposes.

It appears likely that the biggest gas engines of the near future will be supplied by gas from blast furnaces. The immense volumes of gas from these furnaces which are practically wasted today might be utilised in large engines. Fig. 7 shows Mr. Thwaite's large blowing engines at Claycross Ironworks, near Chesterfield. In this design two horizontal power cylinders drive a central vertical air-blast cylinder, this arrangement being suitable for a proper distribution of the power to the air.

gas. Governing is effected by throttling the explosive mixture; the frequency of the impulse being the same for all loads, the predetermined ratio of gas and air remains constant, but the quantity of mixture admitted to the cylinders is controlled by the governor, and each impulse is in proportion to the load carried by the engine. The gas is reduced to atmospheric pressure by means of a suitable pressure regulator, and is mixed with the air just before passing through the balanced valve which is operated by the engine governor of the fly-wheel type.

The use of three cylinders, coupled with the method of governing by throttling, results in a very even turning moment of the crankshaft and renders the engine suitable for coupling direct

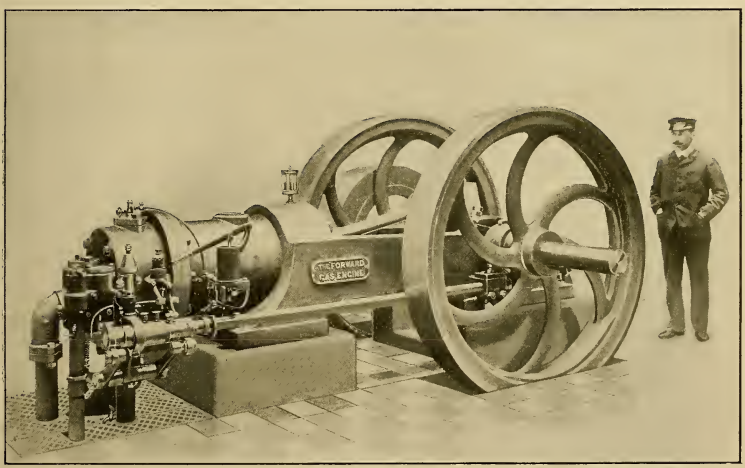


FIG. 9.—A 100 H. P. ENGINE BUILT BY THE FORWARD ENGINEERING CO., LTD., BIRMINGHAM

Naturally, the blowing of the furnace forms a particularly suitable first form of gas utilisation.

Tangye's 200 B. H. P. three-cylinder vertical gas engine, Fig. 8, works on the Otto cycle, the cranks being set to receive an impulse at every two-thirds of a revolution. It is capable of developing 225 brake H. P. with producer

to dynamos. The cylinders are carried on a cast-iron standard of the enclosed type, bolted to a cast-iron base which carries the main bearings for the crankshaft and also forms an oil bath. The ends of the connecting-rods work into the oil bath, and the oil is thrown over the whole of the internal working parts, the cylinders and bearings thus being

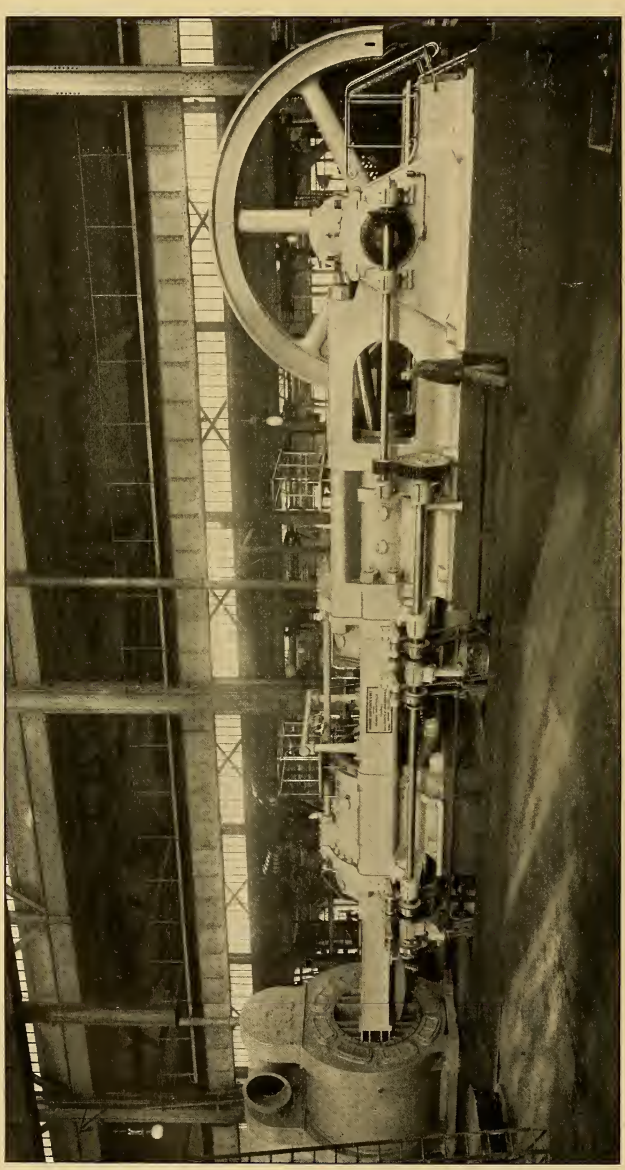


FIG. 10.—A 1200 H. P. TANDEM GAS BLOWING ENGINE. THIS IS AT PRESENT THE LARGEST GAS ENGINE IN THE WORLD. THE GAS CYLINDERS ARE 51 INCHES IN DIAMETER, AND THE BLOWING CYLINDER IS 73 INCHES IN DIAMETER. THE STROKE IS 55 INCHES; SPEED, 80 REVOLUTIONS PER MINUTE; TOTAL WEIGHT, INCLUSIVE OF THE 33-TON FLYWHEEL, 237 TONS. BUILT BY THE SOCIETE ANONYME JOHN COCKERILL, SERAING, BELGIUM

efficiently lubricated. Air at a pressure of about 150 pounds per square inch is sufficient to start the engine easily and steadily, one of the cylinders being converted into a compressed air motor by means of a handle attached to one of the admission valve levers. Engines of this type are at present being built capable of developing 400 maximum I. H. P. and 350 maximum B. H. P.

The Forward engine of the Forward Engineering Company, Ltd., of Birmingham, is shown in Fig. 9. In this engine there is a filter on the air inlet to keep dust out of the engine. A porcelain ignition tube is employed with a timing valve, and the Otto cycle is followed.

Fig. 10 illustrates what is to-day the largest gas engine in existence, built by the Société Anonyme John Cockerill, of Seraing, Belgium. It is rated at 1200 H. P., and has two cylinders, 51 inches in diameter and 55 inches stroke, arranged tandem fashion, and working a 73-inch blowing cylinder. The working speed is 80 revolutions per minute. The total weight of the engine, including the 33-ton fly-wheel, is 237 tons.

There are now about fifty firms building gas engines of 200 H. P. and upwards. Most of the large engines have been made by, or for, Continental firms. The reason for this is simply that on the Continent the use of blast furnace gas, as first advocated by Mr. Thwaite several years ago, has been liberally considered. Such large volumes of gas were available that it tended to the supply of large engines which consume this hitherto neglected source of power. British, and it may be added American, ironmasters have been slow to appreciate the advantages, and have thus deprived the makers of gas engines of the opportunity of turning out gas engines of large power for which they are as able and competent as any other firms.

It is seven years since the writer was asked to make the test previously referred to of the first gas engine ever run with blast furnace gas. This was a small engine of under 20 H. P. at the works of the Glasgow Iron & Steel Company, at Wishaw. The engine drove the electric light plant for the furnaces, yard, and offices, and is still doing so. Though small, it showed an output of electric energy per pound of coal used in the blast furnaces equal to the best steam engines, and convinced the writer that a new power of immense value had been made available. After this progress was rapid—on the Continent—but it has been slow in Great Britain, and with millions of cubic feet of gas going to waste. The curious sight is seen of special gas producers being put up to generate gas for power purposes,—a proceeding not unlike pumping water uphill in order to get a water power.

While the blast furnace has done, and will do, so much for the large gas engine, it may be pointed out that gas power plants have probably failed in the past because of the difficulty with premature explosions, pointed out above as due to gas too rich in hydrogen. Blast furnace gas has been called miserable stuff, because it will hardly burn at atmospheric pressure in the cold vicinity of steam boiler plates, and Mr. Tom Westgarth states that when burned under boilers it will not produce more than one-fourth the power that it will give when used in gas engines. More favourable estimates give the ratio at even a sixth. In any case, the difference is so great that the gas engine must inevitably be the future user of blast furnace gas.

Some indicator diagrams from the Thwaite blowing engine at Claycross show well the form advocated by the writer,—the explosion line with pointed high running peak being absent and the diagram being fuller in body than when the high peak is allowed. The explanation of the anomaly is simple. The early intense explosion causes high temperature and would be excellent if the object were to heat the water jacket. But the object is to heat the working fluid and to change heat into work as directly as possible. It is thus sounder practice to add heat to the gases while they are expanding and losing heat, than it is to produce an initial high temperature and pressure, the effect of which is, on the one hand, to add more heat

to the jacket water and, on the other hand, to produce a heavy pressure of the crank shaft on its bearings and of the crank pin on the head of the connecting rod, pressure which acts simply as a braking effort on the rotation of the engine.

Thus early ignition, which would perhaps be thermodynamically correct in an adiabatic cylinder, becomes assuredly wrong practice in a water-cooled cylinder, both economically and mechanically. These points may be the more lengthily considered because they are so opposed to the ideal that has grown up and has been based on steam practice and on the æsthetic notions that have prevailed in regard to the form of diagrams.

Thus, step by step, gas engine practice differentiates itself from steam practice. Yet it is this very differentiation that helps on such mechanical parallelism as the use of double-acting engines with piston rods and stuffing boxes.

COLLAPSES OF FURNACE CROWNS

A SUGGESTED EXPLANATION

By H. M. Rounthwaite, M. Inst. N. A.

THE following explanation of the gradual collapses of boiler furnace crowns, with which all engineers, particularly marine engineers, are familiar, was offered by the writer in a paper presented recently before the Institution of Naval Architects.

When a furnace crown is under usual working conditions, the side exposed to the fire will be hotter than the side in contact with the water, and this difference of temperature will depend upon the intensity of the combustion, the pressure of steam carried, the condition of the surfaces as regards soot, scale, grease, etc., and also to a slight extent upon the thickness of the plate. Also, the hottest part of a furnace crown is probably that adjacent to the longitudinal centre line, since that part is placed normally to the direction in which most of the radiant heat leaves the fire, and is also worse off as regards water supply than other parts. The water supply to the central portion of the crown must come mainly from the sides, and must, therefore, contain a considerable proportion of steam bubbles which have not had time to rise clear of the plate lower down the curve of the crown; and, as the currents from the two sides meet and change direction near the centre line, an eddy is formed, and the water close down on the centre of the plate tends to be somewhat stagnant, and so to contain a greater proportion of steam bubbles than the water elsewhere, and, therefore, to have also a higher mean temperature.

Let it be granted, then, that the fire side of the plate is hotter than the water side, and that the temperature is a shade higher near the centre line than elsewhere. If the crown plate were a free strip of metal, as indicated by Fig. 1, this distribution of heat would cause

FIG. 1

it to change its form from that shown by the full lines to such a one as is indicated by the dotted lines, owing to the greater expansion of the layers on the fire side. The furnace tube does not consist of such free strips of metal, but it is well known that some action of

this kind does take place, and that, in spite of the restraining forces, or resistances, the furnace tube does assume a more or less oval form in cross-section, the sides going out and the crown and bottom plates approaching each other.

The resistances prevent the sides moving out to anything like the distance due to the difference in the expansion of the two faces of the plate, and the result is that the inner layers are crushed up to some extent, the outer ones being at the same time possibly stretched to some minute extent; but the marked effect is the crushing.

As another example of a similar action, the case of a hot bearing-brass may be referred to in passing. The heated inner layer cannot at once expand, because of the restraint due to the cooler outer layers, and it is crushed in consequence; and, when cool again, it shows minute cracks, which are caused by the action of the shaft pressure in restoring the inner layer to its original length.

Assuming now that the layers next the fire have been more or less crushed in this way, suppose further that the fire-door is opened for the purpose of firing or of cleaning the fire, or that the ashpit damper is closed, or the fire banked, and that the furnace temperature falls in consequence. Then, if the crown plate were free, it would tend to return to its original form as the temperature fell, but, owing to the crushed and shortened inner layers, it would go

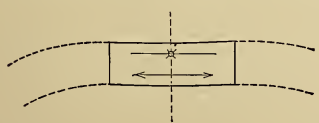


FIG. 2

further and become an oval with the longer diameter vertical if it were allowed to become quite cool again. But the crown plate is restrained, not free, and it probably does not return even quite to its original semi-cylindrical form when cooled, because the exposure to heat has been long, and some molecular re-adjustment will have taken place, whilst the frequent periods of cooling are short. Thus, the crushed layers on the fire side are trying to pull in the sides of the furnace and the resistances are preventing more than a partial re-

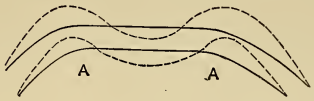


FIG. 3

adjustment of form, with the result that the crushed layers are now subjected to stretching, or are in a state of tensile stress. But this tensile stress in the layers next the fire sets up a corresponding compressive stress in the layers next the water, and this stress is always tending to crumple them up or crush them together. The important point is that, although these stresses are not sufficiently great to produce immediately a perceptible effect, the same series of actions and reactions is gone through dozens of times every day during which the boiler is under steam, the furnace tube "breathing" with every change of temperature, and their effect is cumulative.

An exactly parallel case, which will serve as a very good illustration, is that of the continued shrinkage of an iron ring when alternately heated to redness and quenched in cold water. The outer layers are suddenly caused to contract, and, in so doing, they crush the inner portions which are still hot; and this effect may be produced a number of times, the ring increasing in cross section and diminishing in diameter with each repetition.

If, now, stresses, as above described, act in every element of the furnace crown, their disposition being that indicated in Fig. 2, their general tendency is evidently to straighten the curvature and eventually to produce a minute flat at some point, that point being determined as is the point at which contraction of area takes place in a tensile test

piece, namely, by some defect or weakness too slight to be observable. And in the case of the furnace crown, the minute flat will evidently tend to appear at the hottest point in the circumference,—the top.

Let the full line in Fig. 3 represent such a flat after the cumulative effect of the forces has made it quite perceptible, but drawn for clearness in an exaggerated manner. Then it appears that, as regards any compressive stress that may now come upon the inner layers, there are two weak points at the angles *A*, *A*, and the crushing effect of such a stress would be localised at these points, with the result that the section would tend to gradually take the form indicated by the dotted lines, *i. e.*, the shoulders would hunch up and the centre part go down, thus gradually producing a pocket in the crown plate.

The explanation of the fact, so often observed, that such a pocket will come down so far and then stop, may be that, when it attains a certain depth, it acts as an expansion joint, and allows the furnace tube to "breathe" as much as the changes of temperature compel it to. That when set back such a pocket tends to form again in precisely the same position is exactly what might be expected when the material is injured, quite imperceptibly no doubt, but still fully enough to again determine, or localise, the effect of the continually acting stresses.

As to the effects of grease and scale, although these would hasten and intensify the action in question, it is clear that they are only accessory or subordinate causes, the primary cause being simply change of temperature. It would also follow, if this is the real cause of these gradual collapses, that they will be less frequent in boilers fitted with mechanical stokers, other things being equal, and it would be interesting to know whether any such difference has been observed.

Further, it would follow that stiffened and corrugated furnaces will be more liable to collapse than those which can change form, or "breathe" more freely, since it is the resistance to breathing that causes the trouble. A plain furnace of rather thicker plate should have the advantage over those of more rigid type, as the depth of girder (*i. e.*, the difference between the outside and inside radii) is less in the former than in the latter. Also, the short and rigid furnaces of marine boilers will suffer more from these collapses than the longer and less rigidly held furnaces of Lancashire boilers. And the cure lies evidently in such manipulation of the furnace when at work, or alterations in its construction, or in such additional appliances, as will reduce changes of temperature.

MACHINE TOOLS FOR ENGINE BUILDING

By George T. Reiss

THE object of this paper, prepared originally for the Engine Builders' Association of the United States, is to present in a practical form some of the special features applied to machine tools, having reference more especially to their adaptability to economically finish engine parts. The main parts entering into the construction of engines will be taken up successively and the methods of operating on them with machine tools will be described. Beginning with the main shaft and piston rod, these parts are now mostly finished on the lathe. Recently, however, rapid grinding machines have come into use, and, for finishing piston rods and the main shafts of the smaller sizes of engines, are superior to the lathe both as to quality of work and the time required to do the work. In this case the lathes need be used only for rough-

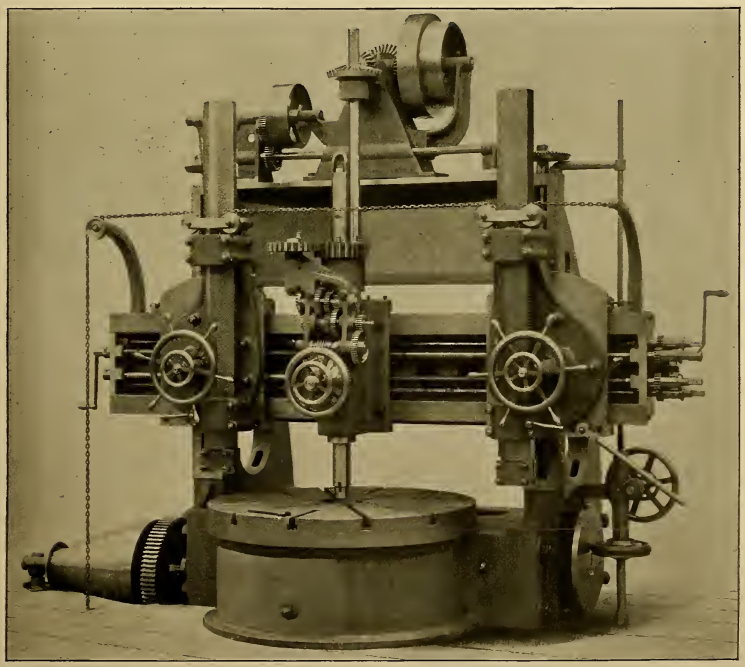


FIG. 1.—FOR BORING THE HUB SIMULTANEOUSLY WITH TURNING THE RIM OF A PULLEY OR FLYWHEEL, A SPECIAL CENTRAL HEAD IS PROVIDED, ITS BORING BAR HAVING INDEPENDENT DRIVE AND FEED

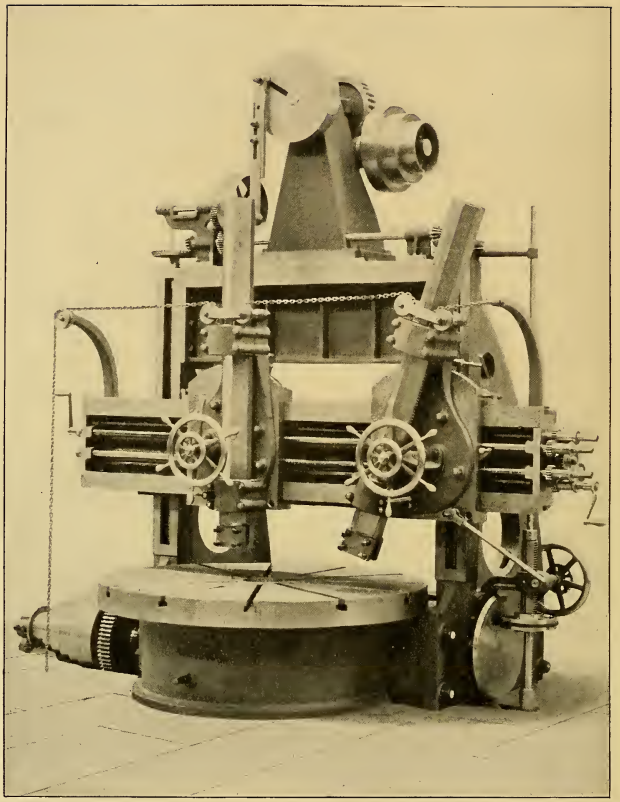


FIG. 2.—ONE OF THE HEADS HERE HAS A CRANK-DRIVEN SLOTTING ATTACHMENT FOR CUTTING KEYWAYS

turning, after which the piece is ready to be turned over to the grinding machine; in this it is reduced to accurate size in a very economical manner.

For turning and boring fly wheels and pulleys, no machine is better adapted than the vertical boring and turning mill. The great advantage of laying the work flat upon a horizontal table and the possibility of using two cutting tools on the work at one time makes the boring mill the ideal machine for this class of work. Usually the operation of turning the wheel rim is completed first, after which one of the heads is set to the centre to bore out the hub.

An attachment is shown in Fig. 1 for boring the hub at the same time that the rim is being turned. This attachment consists of a central head, bolted to the center of the cross-rail and furnished with a boring bar having independent drive and feed. As the boring bar is provided with a range of speeds and feeds, it is evident that any diameter of hole can be bored at the proper speed

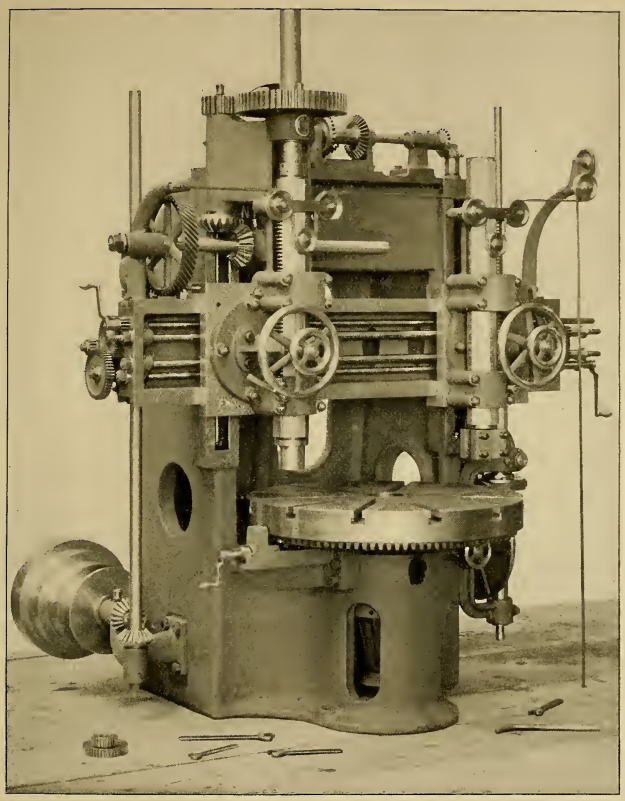


FIG. 3.—CRANK-PIN EYES CAN BE BORED WITHOUT RESETTING THE CRANK BY PROVIDING ONE OF THE BORING MILL HEADS WITH A BAR HAVING INDEPENDENT DRIVE AND FEED

at the same time that the rim is being turned.

Frequently where the boring mill is furnished with two heads, one of these is provided with a crank-driven slotting attachment, used for slotting the key-way in the hub of the fly-wheel as well as slotting the key-way in the crank disk. This attachment is shown in Fig. 2. It is provided with a number of speeds for varying lengths of stroke, and as the boring bar, which acts as a slotting ram, can be set at any desired angle, the required taper in the key-way is readily obtained.

Another special feature applied to boring mills, very useful in boring out the crank-pin eye, is illustrated in Fig. 3. It is frequently the custom in finishing cranks to finish the surface of the crank and bore out the centre for the main shaft at one setting, then to reset the crank to centre it for the crank pin eye, boring this at the second setting. This not only makes two settings of the crank necessary, but also requires the

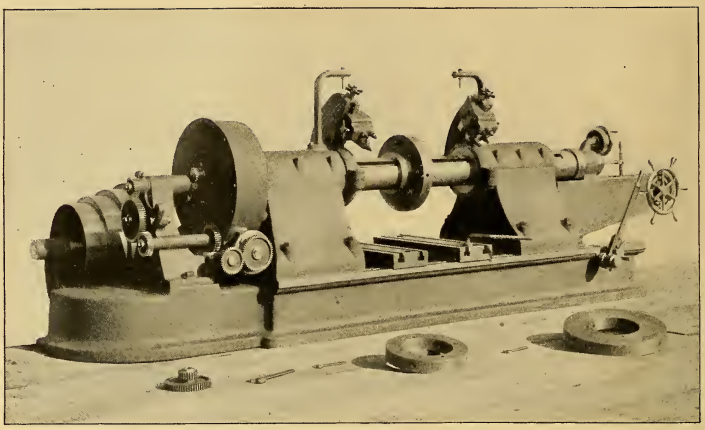


FIG. 4.—A LOCOMOTIVE CYLINDER BORING MACHINE

use of a large mill. To obviate this, one of the heads of the boring mill is provided with a bar having independent drive and feed. When it is desired to bore the crank-pin eye, the table is simply brought around to the proper position and locked in place by a suitable clamping device. The boring head is then adjusted to the proper distance from the centre on the cross-rail and the crank-pin eye is bored accurately to size by a double-ended cutter.

Locomotive builders use a special machine for boring out the crank-pin eye in the driving wheels of locomotives after they have been mounted on the axle. It has often occurred to the writer that in cases where great accuracy of alignment is required in the crank-pin it may not be the best practice to bore out the crank-pin eye until after the crank has been pressed on the main shaft. The machine illustrated in Fig. 5 accomplishes this in the following manner:— The bed-plate is provided with one or two headstocks, depending on whether it is to be used on a shaft having one or two cranks. The shaft is supported in bearings on the bed and with accurate adjustment, and the alignment is made by centres fitting in the headstocks on the machine. An adjustable boring spindle accurately aligned with the centre-line of the shaft is adjusted to the proper position from the centre and bores out the crank-pin eye with a double-ended cutter.

The economical boring of the cylinder is worthy of attention. Locomotive builders have adopted for this purpose a simple and efficient machine of the type illustrated in Fig. 4. In this machine, which is provided with two facing heads, the latter are not clasped to the boring bar, but are attached to heavy sleeves revolving in the headstocks. The boring bar, which is provided with a travelling head, receives its motion from the sleeve revolving in the left-hand headstock, and, by means of spline and key, drives a sleeve and facing head in the right-hand headstock. The travelling cutter head receives its feed-motion from the driving mechanism of the machine.

The cylinder is readily put into place, the bar being for this purpose withdrawn by means of a rack and pinion into the right-hand head, leaving the space between the two headstocks entirely free to take in the cylinder. The right-hand headstock being adjustable on the bed, the two facing heads are brought into operation at the same time with the bor-

ing head. By this means the operations of boring and facing the flanges can be done at the same time.

Sometimes it is necessary to turn the rims of the cylinder flanges. In that case the facing heads are provided with a proper feed for the purpose. The great advantage of this machine lies in its stability, it being possible to use it on comparatively long cylinders with a proper length of bar, and at the same time bringing the supporting headstock close up to the cylinder when boring short cylinders. The facing heads are more steadily supported by the sleeves than would be the case if they were clamped to the boring bar.

Where cylinders for ports arranged, as in the Corliss type, a special port-boring attachment is applied. This is

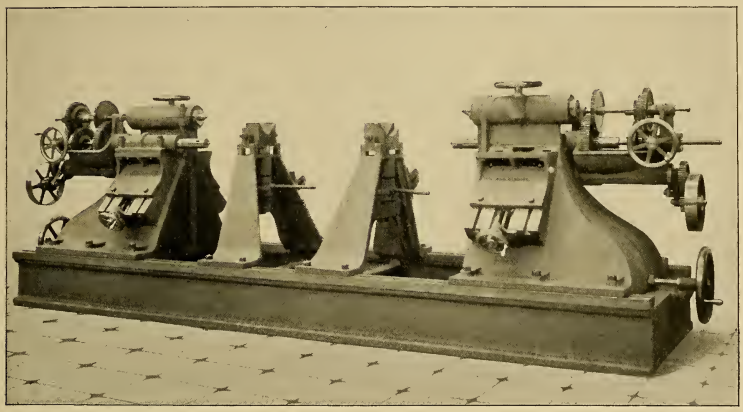


FIG. 5 —A MACHINE FOR BORING OUT LOCOMOTIVE CRANK-PIN EYES

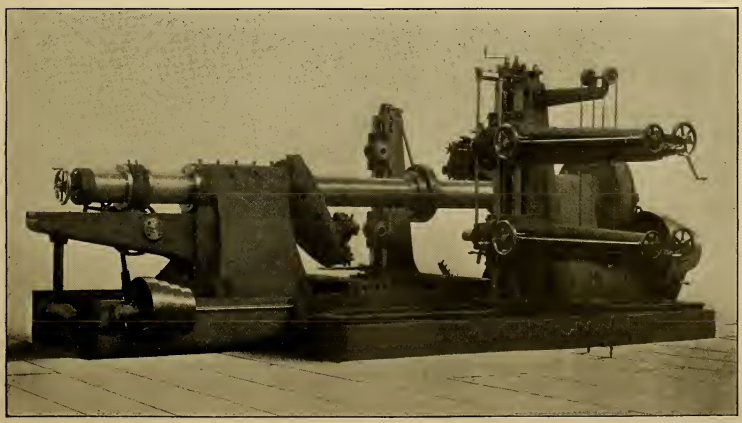


FIG. 6.—FOR BORING CORLISS TYPE PORT CYLINDERS A SPECIAL ATTACHMENT HERE ILLUSTRATED IS APPLIED TO THE MACHINE SHOWN IN FIG. 4

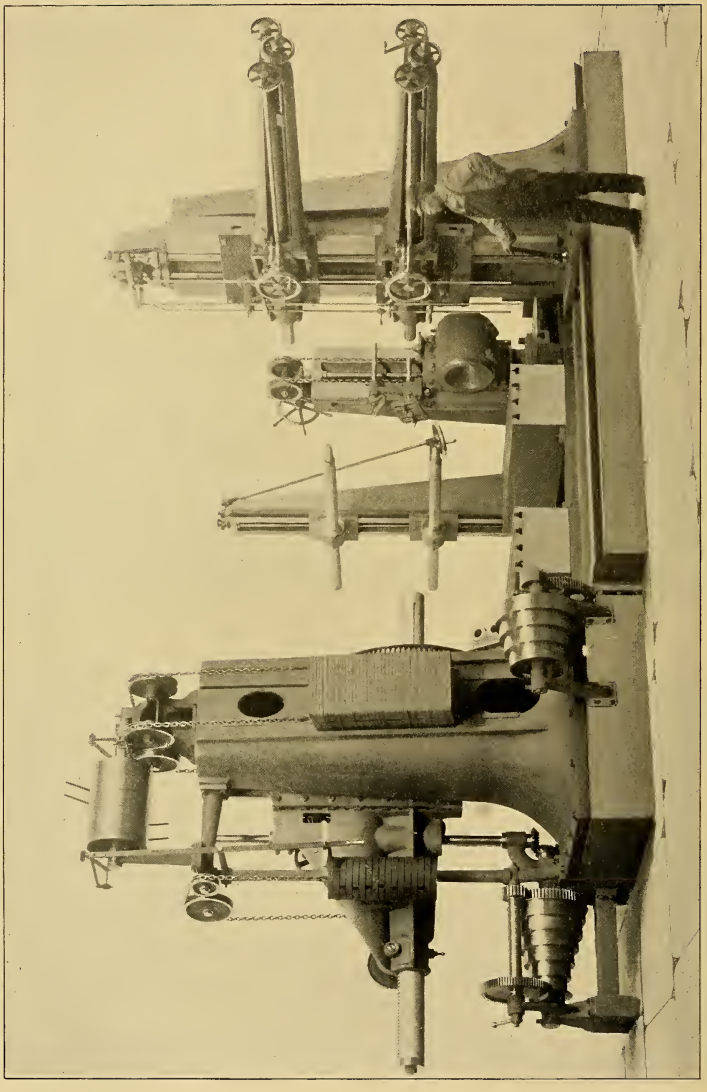


FIG. 7.—A MODIFIED FORM OF THE MACHINE SHOWN IN FIG. 6, WITH THIS THE NECESSITY OF BLOCKING UP THE CYLINDER IS AVOIDED

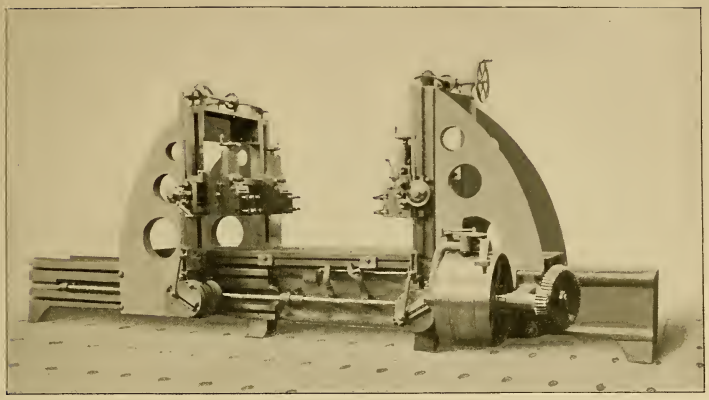


FIG. 8.—A PLANER WITH TWO PAIRS OF HOUSINGS FOR PLANING THE STUB ENDS OF LOCOMOTIVE CONNECTING RODS

shown in Fig. 6. The machine has the same features as the one previously described, as far as pertains to the boring bar and the facing head. The port boring heads are adjustable vertically and horizontally, the borings at the ends of the boring-bar being accurately set by graduated scales. The use of this machine enables all of the operations of boring the main bore, port-boring and facing of flanges, to be done simultaneously, and, as the longest operation is

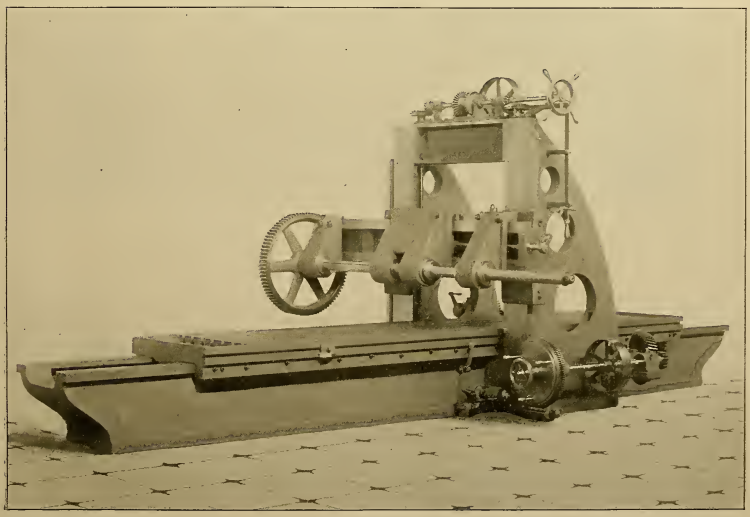


FIG. 9.—A SLAB MILLING MACHINE SUBSTITUTE FOR THE PLANER SHOWN IN FIG. 8

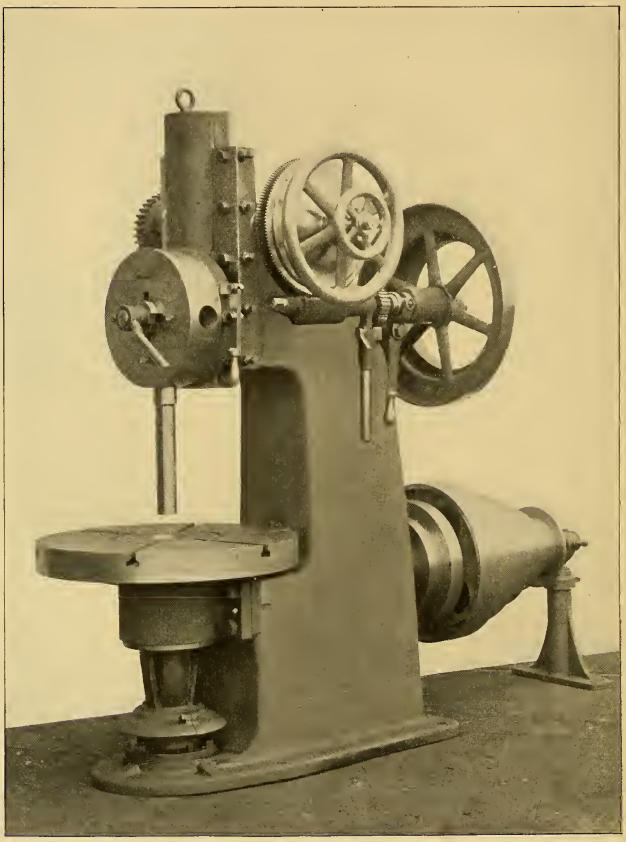


FIG. 10.—A VERTICAL BORING AND TURNING MILL FOR THE SMALLER PARTS OF ENGINES

boring of the main bore, the time required for this becomes a measure of the time for finishing all the boring operations on the cylinder. As all of the operations are done with only one setting of the cylinder, a marked saving of time is effected.

A modified form of this machine is shown in Fig. 7. In this the main boring bar is not fixed as to centre height, but can be adjusted vertically to suit the varying heights of the cylinders. By the use of this machine the necessity of blocking up the cylinder is avoided.

A modified form of the cylinder-borer with a port-boring bar can be used to great advantage in boring out the guides in the main bearing of the engine frame. It is quite evident that the operation of boring of the guides and main bearing at one time and with only one setting of the frame not only results in saving of time, but also insures greater accuracy in the work. Users of the Corliss cyl-

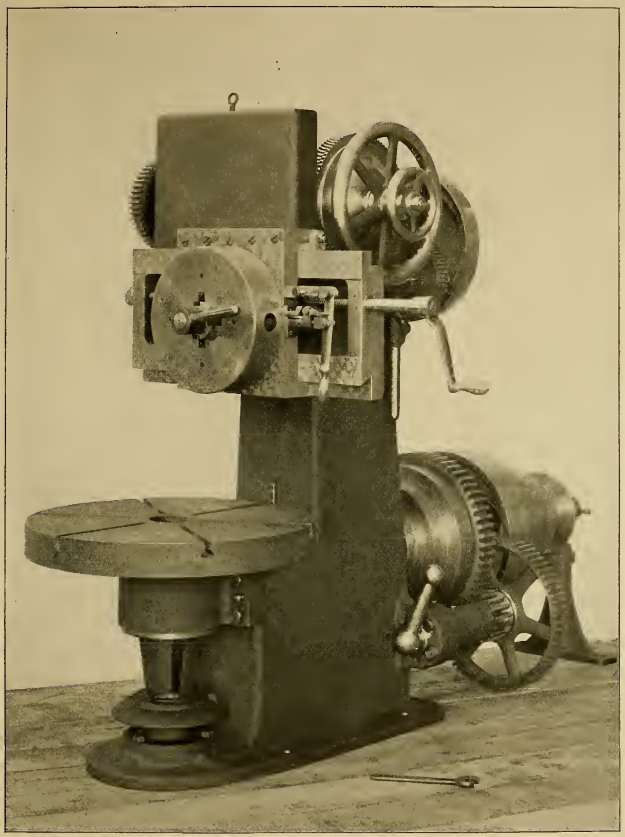


FIG. 11 —A MODIFIED DESIGN OF FIG. 10

inder-borer with port-boring attachment accomplish this by using a shorter bar to bore the guides. This bar, instead of reaching across to the opposite headstock, is supported in a yoke resting on the bed of the machine and straddling the engine frame. One of the port-boring bars is brought to the proper position for boring the main shaft bearing. It is evident that a similar attachment for boring the main shaft-bearing can also readily be applied to the cylinder-borer shown in Fig. 4, first described.

For the boring and turning of eccentric, eccentric straps, pistons and piston rings, a vertical boring and turning mill is a much more efficient tool than the lathe. The work can be more quickly adjusted on the table, which latter, for greater convenience, can be readily supplied with self-centreing or independent chuck-jaws, and, as the boring mill is usually supplied with two

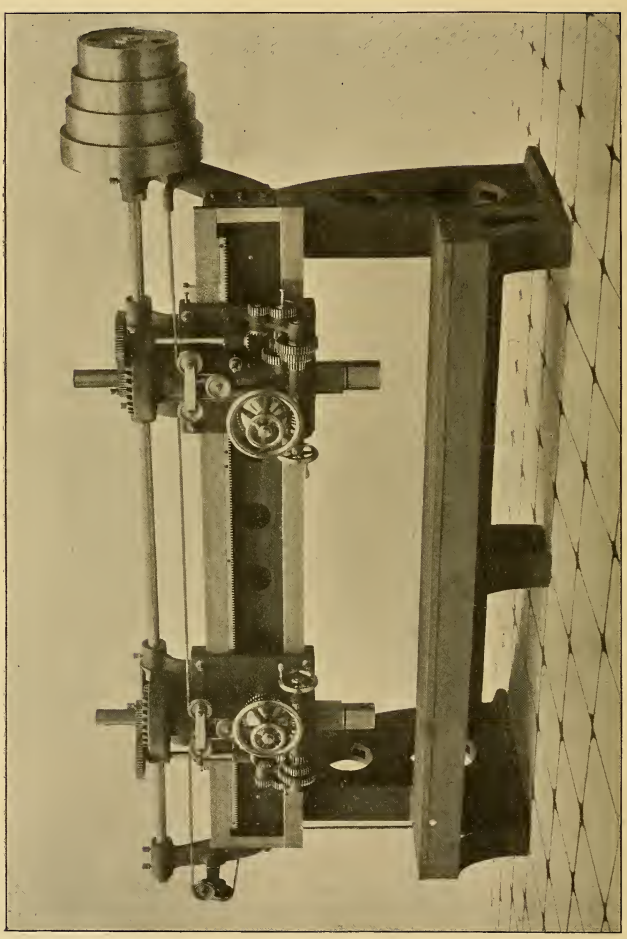


FIG. 12.—A MACHINE FOR BORING OUT LOCOMOTIVE CONNECTING ROD BRASSES

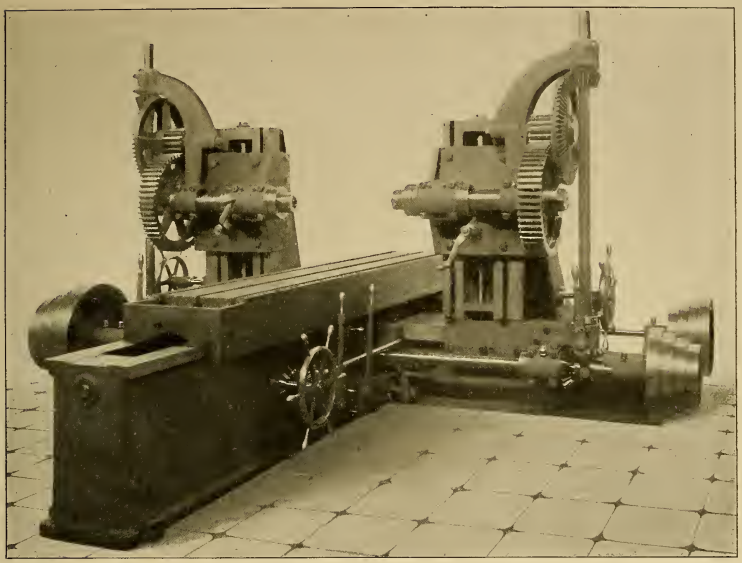


FIG. 13.—AN END-MILLING MACHINE ENABLING THE TWO SIDES OF A CONNECTING ROD TO BE MILLED AT THE SAME TIME

tools, it can be worked simultaneously. Its advantage over the lathe for this class of work is apparent.

For boring the smaller parts of engines an economical and convenient machine is the vertical boring and turning mill shown in Fig. 10. A modified form of this machine, not only useful for boring, but for turning as well, is shown in Fig. 11. The use of a turret enables the placing of the tools, such as drills, boring bars, and reamers, into the machine at the same time, avoiding frequent changes. The turret boring and turning machine has been found very useful in finishing piston rings. Many users finish the outside and inside surface of the ring at the same time by the use of a forked tool placed in the turret, and when the turning and boring operation is completed a cutting-off tool, also placed in the turret, is brought into requisition.

The finishing of connecting rods has always been one of the expensive operations in engine construction, and there has always been considerable discussion whether it is better to finish the stub ends and straps by planing and slotting, or by milling. It is the opinion of the writer that ultimately the milling operation will come into more extensive use for this purpose. At present many locomotive builders plane the stub ends of connecting rods on a planer, like that illustrated in Fig. 8. This machine is provided with two pairs of housings, each pair carrying a cross-rail, having one or two heads, as the nature of the work may require. One pair of housings is adjustable on the bed to suit the various lengths of rods. The table runs at the same speed in both directions, utilising the backward as well as the forward stroke for cutting.

In opposition to planing, slab milling has been frequently employed, using for this purpose a machine of the type shown in Fig. 9. In this case the long cylindrical milling cutter is mounted on

the arbour between the heads and mills off the top surface of the stub; it can also be used in milling off the sides of the strap. Sometimes the milling cutter has a combination form which enables the milling not only of the top surface, but also of the two sides of the stub.

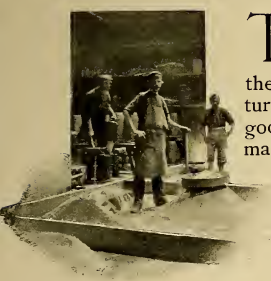
Another form of milling machine, adaptable more especially to milling on the face of the milling cutter, is shown in Fig. 13. In this machine the heads carrying the cutters can be brought very closely together and the two sides of the connecting rod can be milled at the same time. End milling is in many respects preferable to slab milling, requiring for the purpose less expensive cutters, enabling a much quicker feed to the table, and avoiding the great pressure on the work and machine which is consequent on the use of slab mills.

For finishing the surfaces of brasses to fit the strap, the use of the milling machine is far more economical than is a planer or shaper for the purpose. For boring out the rod brasses after being fitted into place, a convenient and efficient machine of the type illustrated in Fig. 12 is now frequently employed by locomotive builders. This machine is provided with an accurately aligned table upon which the connecting rod is placed, and the two heads on the cross-rail can be adjusted to an accurate scale for distance between centres. The boring of the brasses is usually done with the double-ended cutter inserted in the spindle, and results in the holes being accurate in alignment and distance.

The machine tools here described and their special features are the results of suggestions and recommendations to the tool builders that are often made from time to time by the builders of locomotives and stationary engines, and it is the hope of the writer that in presenting them here they may help toward that goal which all manufacturers are striving for, mainly, greater economy and reduced cost of production.

THE PHILANTHROPY OF SELF-HELP

By Louis Bell, Ph.D.



THE profound economic revolution of the last quarter-century has wrought, for good or ill, a permanent change in the relation of human labour to its environment. Enthusiasts may, here and there, and for a brief season, raise the ghosts of dead industries into the pallid and shadowy phantasm of activity. Dreamers of heroic mould, like the late William Morris, may picture the uprising of primeval social forces to tear down the superstructure of a presumptuous civilisation, and to build anew upon its eternal foundations.

But enthusiasts and dreamers are alike powerless to turn back the wheels of Fate, and to call up from the levelled dust of the past the conditions which evolved the Florentine craftsman of the fourteenth century or the artisan of the eighteenth. The Past has buried its dead, and we live to-day in a world which is industrially as different from that of a hundred years ago as is the latter from the times and empires of the pyramid-builders. We have to deal with the Present, huge, iron-handed, imperturbable; to turn its Titanic powers, for evil or righteousness, to such use as we best may, to rescue the best of the older world from annihilation and to wield it to all that is worth the saving in the new.

The day of handicraft as the dominant factor in the world's work has gone, irrevocably replaced by the age of organisation, of centralisation, of automatic machinery, and man must find his place under the new régime as he found it under the old. There have been innumerable gospels of sentimental nonsense preached over the ideals and inspirations of the mediæval workman. We instinctively think of artists like Cellini, happily forgetful of the countless hordes of knaves and bunglers who, in lack of wit to dodge the hangman, have unwillingly wrought with clumsy hands abominations which have cumbered oblivion since the days of Tubal Cain and Hiram of Tyre.

The door of time-stained, curiously carven oak, fashioned by cunning fingers three hundred years ago, may still remain as a monument of patient skill; but how about the other ninety and nine, ill fitted and badly hung, none the more substantial for their wooden latches, that have been split up for firewood by exasperated householders in generations long gone by?

The dilettante prattle, too, of the cathedral builders, men illumined by the fervour of their holy task, inspired by dreams of what no eye hath seen, but in the cold uncompromising light of history their cowled forms shrivel dismally. If the pilgrim wanders among the ruins of St. Mary's Abbey, at York, his eye will fall on the crumbling achievements of these mediæval worthies—noble Gothic columns with clustered shafts sweeping upward in magnificent symmetry. Without, they are carved with devout and loving care; within, they are filled with as rascally rubble as ever thievish builder foisted upon a city contract. Thus cheating Heaven, the masters passed to their reward, and sorry their lot if Heaven is less lenient than Time.

Likewise there is vast twaddle of the happy golden age of the working man some centuries ago, and solemn computation of day's wages reckoned in

beef and barley. The hopes and aspirations of the workman of the present time are not yet circumscribed by his stomach, and his daily life is crowded with comforts and conveniences which the world had never known in the days of his hard-working forefathers.

There is little need to recount the myriad things that modern civilisation has brought within the workman's reach. Absolutely, he is in better ease than ever before in recorded time, whatever may be his place, reckoned upon a relative scale of material advantages. The incompetent and the unfortunate have never fared well at any time in the world's history, but to-day it is Humanity, not Death, that stretches out the succoring hand.

Certain it is, however, that modern civilisation, with all that may be written down to its credit, has brought attendant evils in its train, evils that are none the less threatening because of the company they keep. The workman of to-day has gained immensely in power of gross accomplishment, but he runs great risk of losing much in power of initiative that his gains will avail him little in the struggle of existence. Yesterday he learned a trade; to-day it is the undivided *n*th part of a trade that stands between the man and want.

The twentieth century conception of a machine shop, for instance, is not an aggregation of intelligent workmen, provided with the most efficient tools and apparatus that ingenuity can devise, and using them with all the cunning that trained minds can suggest. The shop from the present standpoint, is simply a huge machine tool, as void of conscious volition as an automatic screw machine, of which the intelligent operator is the manager and in which lathes and workmen, drills and inspectors, milling machines and labourers, are on one common plane of non-sentiment, co-acting subordination. It is no longer the artisan's business to see that his work is the best that he knows how to do, but merely that it is close enough to gauge to pass the inspector and go on unchallenged to the next stage and the next semi-automatic workman. Human hands are used instead of steel fingers merely where they are the cheaper means for putting a block of material through a given series of more or less complicated motions, and perfection is reached when the one becomes as deft and unconscious as the other.

The man who feeds blanks into a punching press can have no craftsman's pride in his work. If things go wrong, he blames the die maker much as a heated bearing, if it could do more than squeak, might blame the oil-cup that failed to lubricate it in time. And when the feed man loses his job, he is about as capable of independent action as the discarded oil-cup would be. In other words, with the increased general efficiency that comes with organisation, comes also decrease in personal responsibility and initiative. This is the paramount danger in modern organised industry. The greatest problem before the reformer is not how to increase wages or how to decrease hours of labour, but how to win for the labourer the power of self-help. This inspiration once gained, the rest will come of its own accord.

The present paper is the record of how one thoughtful man in a single place has wrestled with this vital problem of labour and the relation of his results to those obtained by others working under other conditions. It contains a lesson in applied philanthropy that students of economics may do well to heed. The scene of the experiments is a large engineering works at Nicetown, near Philadelphia, employing several hundred hands, of which the head and vital force is Mr. James M. Dodge, himself a mechanical engineer of acuteness and originality, as well as the responsible head of the business. Always profoundly interested in sociological problems and in the welfare of his employees, Mr. Dodge has taken advantage of his position by applying in practice some interesting principles of shop management, moulding both departments from ordinary methods of dealing with labour, and a progressive reduction of the hours of work.

The works are well adapted for such

experiments, since they employ all classes of labour, from skilled engineers to ordinary labourers, and produce a wide variety of beautiful and intricate conveying machinery, the economical manufacture of which demands a complex combination of day labour and piece work and the use of a wide range of machine tools. Then, too, the concern has commercially been highly successful, so that whatever difference of opinion may exist concerning the methods employed, failure cannot be charged against them by any stretch of the imagination.

So far as reduction in the hours of labour is concerned, piecework and the extensive employment of automatic tools have generally been considered adverse factors, and more than one intelligent manager has openly recorded his opinion that a lathe or planer simply cannot be used to do in eight or nine hours the ordinary work of nine or ten. The American skilled mechanic, too, has an international reputation for quickness and efficiency that would seem to leave less than the usual reserve upon which to draw in holding up the output during shorter working hours.

As is well known to students of economics, the eight-hour day has made far less progress in America than in Great Britain, and there has always been serious doubt as to whether the American workman had the same "reserve of personal efficiency" with which to make the shorter day profitable to himself and his employers. In other words, the American is perhaps less physically enduring, but more intelligent and active than his transatlantic cousin, and, on the average, dawdles less and works more nearly at his maximum efficiency.

Furthermore, most of the British trials of the short working day have involved the very important change from three working periods to two, the customary halt for breakfast being omitted and all hands starting on a full stomach instead of an empty one. In the writer's opinion this fact alone has made the introduction of short hours vastly easier than it ever can be here and quite vitiates any comparison with American conditions. The British workman may be of different fibre, but assuredly an American crew that started in for two hours' work breakfastless would not only waste half of that time, but would be ripe for a strike or a riot within a week.

The Philadelphia experience with shortened hours, to be referred to here, therefore tells on the subject with far more than usual weight, and it has an important bearing not only on the questions of labour involved, but on the general economics of manufacturing. It began in this way:—About three years ago, Mr. Dodge, who had been running his works on a ten-hour basis, aside from the usual Saturday half-holiday, became convinced that it would be a wise step and a good thing for all concerned if the working day could be shortened a bit. So he called a shop meeting and laid the whole matter plainly before the men for their consideration and decision. His proposition was a very simple, tentative affair, without any affectation of philanthropy about it. He virtually said to the workmen:—

"If you can keep up the output of the works on a nine-and-a-half hour day, you are welcome to the time and I will see that you do not lose anything by it. Shall we try it?"

After due consideration a favourable decision was reached and the new arrangement went into force. The prices for piece-work remained where they were, and wages were unchanged, except that the occasion was taken for raising the pay of a few labourers on a weekly rate, who had proved exceptionally efficient.

The effect was extremely interesting. All hands took hold energetically and the output of the works quickly settled down to a slightly increased rate. The hands who were employed on piecework found no difficulty in maintaining, or even increasing, their usual earnings, and the others kept up to the pace. A small proportion of laggards found during the first two or three weeks that the smarter work was little to their liking, and, getting no sympathy from their more industrious neighbours, drew their

pay and slipped out of sight. Their places were filled and the shop work went smoothly on the nine-and-a-half-hour basis.

One curious feature of the change was the lively discussion which was precipitated as to the place where the half hour gained should be applied. Some workmen wanted leisure in the morning, others preferred a longer nooning, and still others, an earlier cessation of work at the day's end. This matter was finally amicably adjusted by a division of the spoils between morning and evening. The difficulty was a natural one, for the total gain was not yet enough to have a logical position in the adjustment of the day. One of the strongest arguments for the eight-hour day as against the commoner nine or ten hours is that the gain in available time is great enough to have a definite and certain value to the workman. In time of work, study, or recreation, the whole, Euclid to the contrary notwithstanding, is more than equal to the sum of the parts.

Obviously the success of the slight reduction in hours was, logically, merely a preliminary to a further step in the same direction. After a year or so of steadily improving conditions of manufacture, another shop meeting was called and the day was cut another half hour, this time with little doubt as to the result and with the heartiest good will. The conditions were the same as before and the change went very smoothly. This time very few workmen found the quickened pace too hot and the shop quickly steadied down again to an increased output.

The revised schedule has now been in operation nearly a year and the results have been uniformly good. It seems clear that the nine-hour day not only causes no loss, but works a positive benefit to all concerned. Not only is the cost of working the material decreased by the greater efficiency of the labour but the men are uniformly making larger earnings.

These results have been carefully analysed and the improvement in economy is most conspicuous. Without grovelling in minute statistics the broad facts are as follows:—

The labour cost per ton of output for the nine-hour day was 15.5 per cent. less than during the trial of the nine-and-a-half-hour day, and no less than 28.5 per cent. less than the cost during the ten-hour régime. On the side of the workmen there has been scored, in passing from the ten-hour to the nine-hour day, a clear gain of 15.3 per cent. in the total average rate per man-hour and consequently a net gain of about 5 per cent. in daily earnings.

As in every case of increased output, in spite of diminished working time, the cause of so marked a change for the better is worth examination in at least a cursory fashion. It very frequently happens that the introduction of improved methods of manufacture, or of new machinery, or a material change in the character of the product, may vitiate the data from which the facts regarding labour must be determined. In the present instance the product did not vary in kind to any noticeable extent during the period under investigation. The business as a whole has grown steadily, and the management has been quick to adopt improved methods and tools.

In fact, the entire shop has been equipped with electrically driven machines, a very elaborate and complete plant having recently been installed; but this particular improvement is subsequent to the times involved in the comparisons just made. There has been, however, a constant tendency to use faster-running tools and to introduce every labour-saving device that promised good results.

Such steps, of course, improve the output of any manufacturing concern, and, doubtless, have had a bearing on the improvement shown in the shops here considered, but it is the judgment of Mr. Dodge, who has watched the progress of events with the keenest interest, that the excellence of the result is due, in the main, to the earnest and effective co operation of the men themselves.

The ordinary student of economics

has but a vague idea of the daily work in a machine shop. In particular, his notions of the performance of machine tools are wildly wide of the facts. Under every-day conditions the time taken in placing and adjusting the work, in changing from one task to another and in waiting for material, is considerably greater than that during which the cutting edge of the tool is actually gnawing metal. Hence, there is ample opportunity for really alert and enthusiastic labour to force the output even of lathes and planers.

It is now a well-understood principle of wood and metal working that for the maximum economy of the whole process of manufacture every cut should be taken at the most efficient speed,—generally much higher than used to be customary. Clear recognition of this principle and the introduction of improved tool steel have made it feasible to work metal at a rate which would have been considered a sheer impossibility even a few years since. But only intelligent and active workmen can take proper advantage of the situation and force the shop to a condition of efficient production. An atmosphere of fagged and spiritless endurance in a shop is a steady drag on manufacturing efficiency, and the shortening of the working day unquestionably has the effect of putting the men on their mettle and dispelling the sedate melancholia that afflicts the unwilling. The writer does not at all, however, subscribe to the opinion that in a change relatively so small as that made in this instance the favourable result can be in any measurable degree charged to relief of physical weariness or mental depression.

It has been due mainly, if not entirely, to a manly pride in self-helpfulness, and to love of fair play. When men fully realise that their employer proposes to deal squarely with them, first, last, and always, and that the improvement of their wages and condition of labour reats with themselves, they get to work in down-right earnest.

The human element in labour cannot be put aside by any amount of automatic machinery, nor can the man be reduced to the level of the machine in spite of the most earnest efforts of numerous employers. He reckons ill who imagines that he can for any long period keep on increasing the productiveness of labour without increasing its remuneration. That workmen do resent the attempt to make them mere cogs in a money-getting machine for the profit of others, is, upon the whole, vastly to their credit. To establish sound human relations between employers and employed it is not at all necessary to strike an attitude of disinterested philanthropy. The world could

JAMES M. DODGE, PRESIDENT OF THE LINK BELT ENG'G CO., NICETOWN, PHILADELPHIA

not be, and need not be, run on strictly altruistic principles, and self-help,—call it enlightened selfishness if you will,—is the necessary prelude to mutual helpfulness.

It was a keen recognition of this principle that led Mr. Dodge to experiment with a shorter working day with such ocnspicuous success, and the same idea permeates his entire shop organisation in a very complete and thorough-going fashion.

One may as well put aside at once the

crude notion that there is any magical number of hours which limits a man's physical fitness. You can overwork a man just as you can overwork a horse, provided you have the same control of both; but you cannot overwork the man in nine or ten hours against his will. His reserve power is his own and he will not draw regularly upon it unless it is worth his while. Moreover, it is the man himself who is the judge of the facts. And because of this, he prefers to determine by his own efforts his periods of leisure and to employ them as seems to him to be good. And this is why, to the great grieving of many well-meaning persons, from the self-styled "better classes," their officious efforts to "help the working man" go sadly awry. "Soup-house philanthropy" Mr. Dodge grimly calls it, and utterly disclaims the name of philanthropist, unless by it be merely implied a person who practices square dealing with his fellow men.

By which reason there are not to be found about his works any lunch rooms, penny savings banks, insurance schemes, Sunday school, co-operative shops, base-ball grounds, golf links, or other devices for forcing his views of life and recreation upon his employees. In fact, he goes so far as to have a revolutionary theory that instead of hiring a hall and giving a holiday dinner to his hands and their hungry families, it is better to put them in the way of providing their own.

The shop organisation at Nicetown is interesting and refreshingly heterodox. It starts in with the hypothesis that while all men may be born free and equal, they are not equally good working men and hence that the uniform rate of wages is inherently unjust. A dozen mechanics may be doing the same class of work in the shop, but it is long odds that no two of them make the same weekly earnings aside from all question of piece work. A new man is started in on an arbitrary tentative rate and very soon finds his proper plane. When he gets upon piece-work, his earnings depend upon his own efforts, and a premium system is enforced by which the basic piece-work rate rises after a certain minimum output is passed. Thus an industrious workman finds no difficulty in earning good wages, while the lazy one has an incentive to spur him at least into the semblance of activity.

Piece-work is adopted as far as possible as the rule of the shop, although in an engineering works like this there is necessarily considerable labour which cannot be reduced to this simple basis. As a matter of theory, any often repeated operation can be reduced to piece-work, but in some cases it is inadvisable to do so. In some classes of work, too, it tends to carelessness, and is successful just in proportion to the conscientiousness of the men.

It is peculiarly liable to lead to discontent unless administered with vigorous justice, and it requires the wisdom of the serpent to locate justice. In most manufactories there is constant fear on the part of the hands that piece-work prices will be cut as soon as earnings appear to be increasing, and, in all fairness, this fear is often only too well grounded. As a means of defence, the men frequently have a formal or tacit agreement to limit their output which is quietly, but rigidly, enforced.

One instance of this, so striking as to deserve relation, comes to mind. In the armature-winding shop of a certain electrical works, the men, at that time affiliated with no union, had formed an organisation of their own. One of its regulations limited the number of armatures, according to character and size, which any member was at liberty to turn out weekly. Now, it happened one summer that a certain active young man desired to spend a Sunday in the country with his family. So he quickened his pace a bit and completed his weekly quotum of work on Friday afternoon instead of on Saturday noon, and left for his little outing Friday evening. On his return the offender, whose only sin was his industry, was sent to Coventry by his associates and eventually was fairly worried out of the shop.

Of course, the essence of any such occurrence is the spirit of distrust, and

this is sometimes so potent that the general efficiency of the workman is greatly reduced. One of the most difficult tasks in factory organisation is to so adjust the price-current of piece-work that the men will do their best.

In dealing with this troublesome matter in the Nicetown works the principle of self-help has again been applied as the root motive of efficient industry. The base price of piece-work is determined in the ordinary way, by timing various workmen while performing the given operation after they have acquired reasonable proficiency. Then the piece-price is so set as to give a material advance on the daily wage-rate to the average industrious workman. Once thus set, the piece-price is never lowered on account of the increased facility or industry of the hands.

The price fixed is one which is regarded as fair to the employer's interests, and that being so, he does not care how much the men find it for their interest to earn at the task. The premium system tends to keep the shop clear of loafers and that is enough.

All this throws upon the men themselves the full responsibility of their own success. What they gain they have fairly earned and they learn meanwhile the lessons of efficient co-operation, of self-help, of personal responsibility, and the works are the gainers, too, by the skill and the efficient initiative which the men have won for themselves.

Very simple and straightforward this programme looks upon paper, and simple it is in reality, for it merely embodies the fundamental principles of fair play and honest dealing, in which fact lies the difficulty of its general application. Few modern enterprises have that stability of organisation which ensures the continuance of good faith, and it takes stability to obtain a reliable body of workmen. Concerns that expect to make their real profits in the stock market rather than in the factory seldom possess the confidence of their men and generally forfeit that of the public at large; but it is a good thing to know that a conservative management can win the faith of both.

Organised labour assuredly approves of the maintenance of sound fair play between employers and employed, but it balks at the assumption that all men are unequal and does not want even equity as an entering wedge to determine inequality of pay. Consequently Mr. Dodge operates a non-union shop, or rather is absolutely indifferent to his men's affiliations so long as they do their work well. But, union or non-union, he expects them to keep faith with him and each other, and when a few years since a labour organiser brought his shop into line, he dealt with the matter in a highly characteristic fashion. Learning the facts, he shortly took occasion to express his approval of fraternal relations between workmen, and to enquire whether their branch of the union had any grievances.

On these being cordially disclaimed, he inquired what they proposed to do in case, for instance, machinists elsewhere struck and a sympathetic strike were declared. This was a poser, and the men very naturally assured him that having no grievances they would certainly stand by him.

"But," demanded Mr. Dodge, "have you not put yourselves under solemn obligations to strike if you are ordered out? And if you would break faith with the union, can you be trusted to keep it with me? No, if you are ordered to strike, strike you must, to retain your self-respect, and I will see to it that you do."

Nothing more was said, and that branch union silently slipped into innocuous desuetude without further ado.

In relating this incident to the writer, Mr. Dodge suggested a theory of the strong union sentiment, particularly among the younger men, that seems most plausible. They regard and value it, he thinks, quite apart from all relations with their employers, as the *toga virilis* of their trade, once invested with which they are no longer looked upon at home as Tom, or Dick, or Harry, hardly emancipated from apron strings, but as accredited artisans ready to play

a man's part in the world. And he recalled how one capable young fellow, just appointed a foreman, called at his office and asked for a mere line of writing to certify his advancement. "They joss me at home," he said, "and think I am only that boy."

Yet these very youngsters are the bone and sinew of industry if properly trained. They have energy and ambition, and, if given a fair chance, develop judgment and initiative. Workmen nowadays do not learn a trade in the older sense of that term, and therein lies the greatest danger to industrial life. They become, instead, operators on a No. 6, type D, Ajax boring mill, and when business is a trifle dull they are out of work and have to choose between waiting to get back their machines and beginning all over again. Once in the clutches of this highly specialised work there is small hope of escape in the routine of the ordinary large shop. Well-meaning persons may struggle to "improve the condition of the workingman," but so long as he has not the power of self-help there is little hope for him.

It is the remorseless cynicism of the great industrial machine which Mr. Dodge has been fighting against in the studies in shop organisation which he has been conducting. One thing which most strongly characterises his works is the extent to which they are run on individual initiative. He believes in the enthusiasm of youth, the stimulus of responsibility and the incentive of self-help. The men are expected to produce results, to act for themselves to make their brains serve their hands. The labour cost is kept down by skillful planning and efficient methods of work and not by cutting wages. As a result the proportion of so-called unproductive labour—the labour which plans—is unusually large.

And the labour which executes is efficient, first of all, because it has learned that efficiency pays. The men know that they will make good earnings if they are industrious, that the piece-work prices will not be lowered unless improved machinery or methods have made the work proportionately easier, that when they are working for their employer they are also working for themselves.

And more than all, they come to realise that fair play is the order of the day, that they are not merely cogs in a machine, but men whose future depends on their own efforts, men who are expected to think and plan and execute within the limit of their personal responsibility. They know that if they are capable of leaving the shop and setting up for themselves, they will get a Godspeed and a helping hand instead of a kick, and that they will go not with the helpless fragment of a trade but with the capacity and habit of doing their work well.

The moving spirit of the organisation may not be pure altruism, but it certainly is a far finer and more potent thing—the philanthropy of self-help that removes the necessity for charity by fitting men to take care of themselves.

THE GROUNDS AND INSTITUTE BUILDINGS AT TUSKEGEE, ALABAMA

EDUCATING THE AMERICAN NEGRO

THE WORK OF TUSKEGEE INSTITUTE

By H. E. Thomas

WITH the advent in the United States of the negro emancipation enactments of forty years ago very momentous questions, economic and industrial, presented themselves to the four million new American citizens. The problems of getting homes and employment and a financial status so necessary to credit and confidence, as well as other problems pertaining to the new surroundings and responsibilities of the emancipated negro, were to be solved. The greatest question, perhaps, was "What shall be done with the young people?" Many were naturally capable to be leaders and teachers if a proper education could be given them, but a school giving the special training needed for a new people was not available.

A CLASS IN DRESS MAKING

The friends of the coloured youth wished for them an education, of which

BOOKER T. WASHINGTON, THE HEAD OF TUSKEGEE INSTITUTE, IN HIS PRIVATE OFFICE

every detail should tell in their character and usefulness, and well planned instruction on the practical things of life. Men of learning and experience at the South, both white and coloured, exchanged ideas for some years on what was needed to save the coming coloured youth of the section from dangerous illiteracy and lack of industrial activity. It was with these things in view that Tuskegee Institute, at Tuskegee, Alabama, came into existence, and the present flattering indorsement of the work of the institution by all classes of Americans shows the wisdom of those who hoped for a work of this kind years before it was founded.

Booker T. Washington was called from Virginia to Alabama just twenty-two years ago, and started what is now the Tuskegee Institute, in a one-room shanty on July 4, 1881. He had then recently graduated from Hampton Institute, at Hamptor, Va., the pioneer institution for agricultural and industrial training for coloured youth, and had been teaching a school in a remote part of his native State. Prior to his coming, the same committee of citizens who offered him this work had secured the passage of a measure by the Assembly of the State of Alabama, appropriating $2000 annually to pay the salaries of teachers in a normal school to be located at Tuskegee. No provision was made, however, for a school building, or books, or school equipment.

Although about twenty-three years of age at the time, Mr. Washington grasped the situation and got the loan of a one-room shanty from some coloured men in which to hold the first session of his school. The next year he purchased 500 acres of land to begin his permanent school plant, and so vividly has he kept his mental picture of the greater Tuskegee before him, that the school has grown from that one-room shanty, with thirty pupils, to an inclosure of about 3000 acres, over sixty buildings, and 1500 students and instructors, comprising workshops and laboratories, and an agricultural department with over 300 head of live stock.

On the plantation where the first

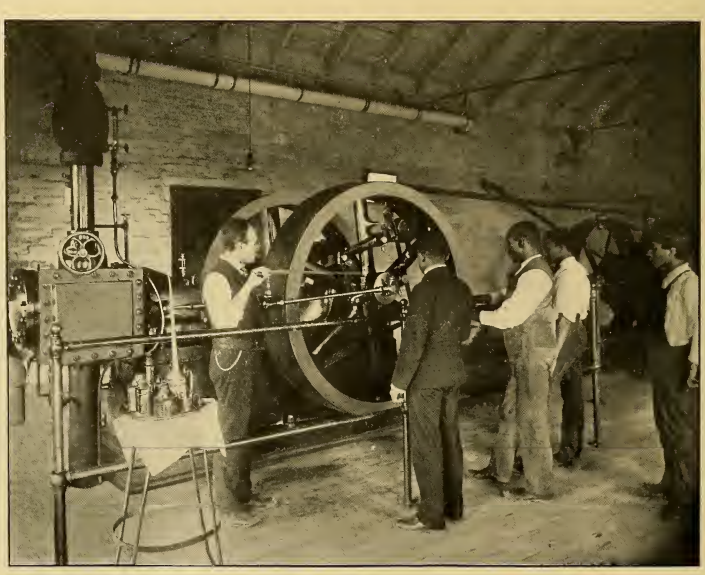
school room stood, the land had become so impoverished by improper agricultural methods that wheat, which had been grown profitably twenty-five years before, refused to mature, and it is not strange, therefore, that Mr. Washington early saw the need of agricultural training in the school. It is a curious fact that in the building-up of Tuskegee there is no brick which was not made on the grounds. A brick yard, in fact, was the first industry started, and the few male students made bricks by hand between school periods till enough were finished to start the first building, and this industry at Tuskegee has grown from that small beginning till now two large brick-making machines, driven by steam power, with a capacity of 3,500,000 bricks per season, are in operation, and most of the bricks used in the vicinity of the school are of the Tuskegee brand.

It is interesting at this late date to recall some of the early contributions to the school by different people in its immediate locality. One gift of four eggs, from an old coloured woman, was brought to Mr. Washington, and another, a pig in a bag, from an old man. It was necessary, however, for the founder to spend his three vacation or summer months in the North and East to secure the funds needed, and during recent years fully half his time has been employed in this way.

The aims of the institution have been to give young colored men and women what they most need,—a normal training in academic lines, and to ingrain them with such principles of moral and ethical worth as to qualify them as teachers and safe leaders in all lines of life among their people. In order that the teachings of the school may not be counteracted by improper home surroundings,

TUSKEGEE STUDENT CARPENTERS PUTTING UP ONE OF THE INSTITUTE BUILDINGS

A CORNER IN THE INSTITUTE MACHINE SHOP

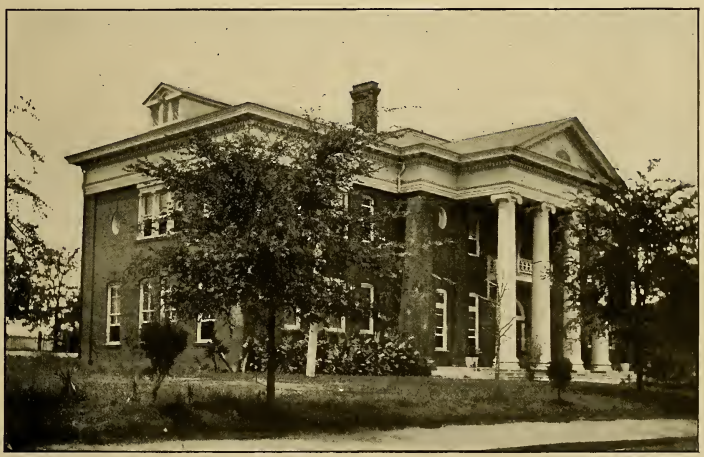


A LESSON IN GOVERNOR ADJUSTMENT

the boarding school idea was early established, thus keeping all the students under proper care throughout their course of training.

The framers of the early policy of the institution urged the learning of some useful industrial pursuit by each young man and woman, thus increasing their earnings and enabling them to maintain a better home and family life; but in recent years large numbers of young coloured people came to Tuskegee from the best schools in the cities of the North and South, many of them high-school graduates, and this has called for a system of post-graduate work which has been established with much success. This, however, has called for higher work in shops and class rooms, in addition to the usual course intended for the youth from the rural districts. The school has exerted a most potent influence in interesting all young people to the possibilities of their section, in its natural resources, in agricultural and other industrial lines, for while the South is generally known as an agricultural section, the advance in manufacturing has been far greater proportionally. Beginning with the year 1880, the South increased its investment in manufacturing 348 per cent. in ten years.

Tuskegee Institute recently had a visit from the manager of one of the large Southern industrial plants, who came to employ ten of the graduates from the metal-working course, and three firemen who could take charge of a modern water-tube boiler plant, with mechanical stokers, forced draught and the latest equipment. Among recent mechanical installations on the school grounds which have been carried to completion by the students from plans of the instructors are a heating plant, an electric light plant, and a bath room for girls, with swimming pool, shower baths, and water heating and circulating features.



THE CARNEGIE LIBRARY BUILDING AT TUSKEGEE WAS ERECTED ENTIRELY BY THE INSTITUTE'S CLASSES IN THE BUILDING TRADES. IT IS THE ONLY LIBRARY EVER GIVEN BY ANDREW CARNEGIE THAT WAS PUT UP UNDER SUCH A SYSTEM OF LABOUR OR BY COLOURED WORKMEN

The construction of the new Carnegie Library by the classes in the building trades has received much attention from visitors, and is no doubt the only library ever given by Andrew Carnegie which

IN THE AGRICULTURAL LABORATORY

A SHEET METAL WORKING DIVISION. ALL THE TINWARE NEEDED FOR THE SCHOOL IS MADE HERE

was constructed under such a system of labour or by coloured workmen. At present three large buildings are in course of erection, and all the problems of architectural design, steam heating, electric lighting and plumbing, are worked out in the school shops and laboratories by the instructors who then give the work to the students in the different branches of building construction as part of their course of study.

An unusual corps of instructors is needed for such original work as Tuskegee presents, and Mr. Washington, the founder, whose name is synonymous with educational development and industrial training in the South, has been ably assisted by young men of his race, who have been trained and experienced in industrial lines and who have helped wonderfully in the building-up of this work. These instructors have not only

A TYPE OF RESIDENCE FOR TEACHERS, CONSTRUCTED BY CLASSES IN THE BUILDING TRADES

been well taught in their special lines, but some of them have had the advantage of actual experience in some of the well-known industrial plants of the country.

At the commencement exercises this year, held in May, each speaker,—a graduate of one of the industrial departments,—had a selected lot of work on the stage to illustrate his remarks. From the agricultural department plants, roots and seeds from the field were used, while from the mechanical department the most striking feature was a steam engine, built in the school machine shop, at work on the stage driving a dynamo which supplied sixty incandescent lamps with current. Above the stage was a design of letters made by coloured incandescent lamps lighted alternately. These furnished the exhibit for a student who spoke on the subject "Generating Electric Currents."

This year an order from a Southern business man for fifty farm waggons was accepted by the waggon-building division of the school, and their construction is now in progress. Nearly all the divisions do commercial work more or less in connection with the regular school work, and the fact that this branch shows increase is perhaps a good testimonial to the work done.

The wide range of service to which the graduates of the institution have been called in both northern and southern fields of labour has surpassed the expectation of the faculty and demands a routine of teaching thorough in details. During the recent war in the Philippines one of the young men who had been a student in the machine and steam engineering division, having enlisted in the 49th Infantry, and being stationed at Parangue in Southern Luzon, while being transferred to Tuguegaroa by water, saved a steam launch, aboard which were the officers of the regiment, much trouble and inconvenience. The launch had

IN THE MILLINERY DEPARTMENT

LEARNING HOW TO COOK

A CLASS IN MECHANICAL DRAWING

collided with an iron sail boat and was rapidly taking water. Seeing that no efforts were made to rid the boat of the water the young man stepped aboard, found the steam jets, and put them to work throwing water from the boat while the native engineers were working at the hole in the side, apparently ignorant that the steam jets were a part of the boat's emergency outfit.

Although Tuskegee receives the greater portion of her students from parts of the country where forty-five per cent. of the population are entirely illiterate, many of her methods have been adopted by institutions of higher educational courses, and a number of educational committees from various parts of the United States and representatives from other countries have visited the school with a view to inspecting the methods used in its industrial and academic work. The desire on the part of the coloured youth for the betterment of all conditions of the section which Tuskegee wishes to reach is amply proven by the fact that over 1300 young men and women were enrolled during the past year and over 150 were turned away for want of room. The enrollment from foreign countries, too, has grown rapidly during the last few years, and many visitors to the institute are astonished at the number of different languages spoken there.

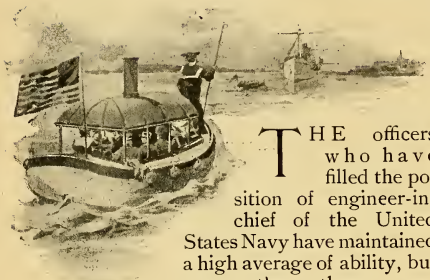
Over twenty branches of industrial work are taught, including the agricultural experiments conducted on the extensive school farms, some idea of which may be had from the fact that ninety head of horses and mules are necessary to do the work and eighty-five cows are cared for at the school dairy. In the mechanical department 450 engine horse-power is necessary to run the machinery. Over ninety-five instructors and assistants keep closely in touch with each youth while in the school, and even after graduation each former student is kept track of by a system of correspondence designed for the purpose. In addition to this, one of the trustees of the institution makes an extended tour each year visiting those who have left school and entered fields of labour. This stimulates all to make their best efforts and is a source of inspiration worth consideration.

In the agricultural laboratories during the past year a series of experiments have been made with a clay found in Alabama. This clay, when chemically treated, has been found to produce a line of rich colours and stains which some specialists from several paint works have pronounced entirely successful as house paints and furniture stains. These have been used on various woods at the school and have interested many visitors during the year.

REAR-ADMIRAL GEORGE WALLACE MELVILLE

ENGINEER-IN-CHIEF OF THE UNITED STATES NAVY FROM 1887 TO 1903

By Walter M. McFarland, late Chief Engineer U. S. N.



THE officers who have filled the position of engineer-in-chief of the United States Navy have maintained a high average of ability, but among them three names stand out pre-eminently,—Charles H. Haswell, the first engineer-in-chief, as well as the first engineer of the Navy; Benjamin Franklin Isherwood, engineer-in-chief during the Civil War; and George Wallace Melville, who, on August 8 of this year, completed a term of exactly sixteen years, during which period the New Navy of the United States came into being. His term of office, if not the longest of any bureau chief in the history of the Navy Department, is certainly the longest for many years.

Admiral Melville's work has been so important and so constantly before the public, which in late years has taken an intense interest in the Navy, that most engineers are familiar with the details of his more recent career. This magazine a few years ago published a careful and sympathetic biography of him, brought down to the date of publication, and it is not intended at this time to repeat these details of his earlier career, but to give a brief account of the more important events which give special significance to his term of office as Engineer-in-Chief of the Navy. It is especially fitting that such a notice should appear just at this time, when he has laid down the office which he has filled with the greatest credit to himself and to the engineering profession, as well as with great benefit to the Government.

It was not necessary, when Melville was appointed engineer-in-chief, for the layman even to ask "Who is this man?" His record as an arctic hero had made his name known throughout the civilised world, and the story of the *Jeannette* showed him to be possessed of those qualities which have contributed to make the administration of his high office so successful. To engineers, it was well known that, besides his arctic record, Melville was one of the foremost engineers in the Navy, a man ready for any duty to which he was assigned, and one who was always picked out for any work of a peculiarly difficult or trying nature. He had been assigned to the *Atlanta*, one of the early ships of the New Navy, to get her into good shape, and, after completing that work, was the engineering inspector at Cramp's.

About this time the attention of Secretary Whitney was called to him as a man likely to carry out efficiently Mr. Whitney's ideas for the building of the New Navy and giving these new ships the latest and best machinery. Accordingly on August 8, 1887, Admiral Melville was appointed engineer-in-chief, and in January of the next year, when Congress was in session, this recess appointment was confirmed. His appointment was distinctly based on merit, and this is proved the more conclusively from the fact that for sixteen years, notwithstanding the change of political parties, he was regularly reappointed, until by reason of age and statute law

he has been compelled to lay down the cares of his office.

Prior to his taking office, the four Roach cruisers had been built and a few of the vessels which immediately succeeded them were in process of construction; but except for these, all of the machinery of our New Navy as it exists to-day was designed and built under his supervision and responsibility, the total horse-power of the main engines amounting to about a million. This is a good place to emphasise the fact that just before Melville took office there had been a movement on foot to depend for plans on foreign designers. Indeed, as is well known, the plans for the *Texas*, the *Baltimore*, and the *Charleston* were purchased abroad. The writer will not go into details about the troubles which resulted from this policy, although they were very great. At all events, with Melville's appointment this policy was definitely abandoned, and he was expected to get out designs for machinery which would be equal if not superior to the best that could be obtained abroad. The writer does not believe that he will be accused either of undue personal regard or blind patriotism when he affirms that the result has proven all that, and more than, could be expected.

Before he took office, Melville was noted for his marked frankness and sincerity in expressing himself and his absolute fearlessness in the performance of duty, so that when he believed it right to express himself openly he never considered what the consequences might be to him personally. It is related that when his first annual report as Chief of the Bureau of Steam Engineering appeared in the fall of 1887, his extreme directness in calling attention to the needs of the Engineer Corps and what should be done to increase efficiency, aroused intense opposition on the part of certain naval officers who went so far as to protest about it to the Secretary and urge that Melville's appointment, which as yet was only *ad interim*, should not be confirmed.

The report was brought to the attention of President Cleveland, but so far from this frank speech having the effect on him which the complainants had hoped, he found that Melville's sturdy honesty was of a piece with his own, and he is reported to have said, "This is just the kind of a man we want. I only wish we had more like him."

This frankness of comment has distinguished Admiral Melville throughout his whole career and has been one of the sources of his great strength, especially with Congressional committees, who soon came to know that he said exactly what he meant, and there was no difficulty in understanding him.

One of the first important things which the Admiral did after taking office was to institute a competitive test of water-tube boilers, for the purpose of installing them on one of our naval vessels and giving them a practical working test. As a result of this, Ward boilers of about five-thousand horse-power were fitted to the coast defence vessel *Monterey*, which was thus the first war vessel larger than a torpedo boat to have such an installation. At the same time water-tube boilers were definitely adopted for all steam launches. They were, of course, a necessity in topedo boats and similar craft.

Although Melville was the first engineer-in-chief of any navy to install water-tube boilers, he did not allow himself to be carried away with a desire to make a great record for progress by adopting them at once for all vessels, but decided to wait until they had been tested thoroughly. The wisdom of this course has been shown by the unfortunate results which have come in some other navies which, adopting water-tube boilers at a later date, went into the matter immediately on a very large scale. Indeed, this conservatism, combined with a most progressive spirit, has been a marked characteristic of the Admiral at all times. Just before he took office, forced draught was adopted for naval vessels, and one chief of a foreign navy, who was not so conservative, wrecked his reputation by building his cylindrical boilers too small to stand up under the stress. It has been a favourite remark of Melville that he never sent a boy to do a man's work, and following this plan with cylin-

drical boilers, our Navy never had any serious trouble.

One of his greatest exploits was the building of the two cruisers *Columbia* and *Minneapolis*. These were the first very large vessels to use triple screws, each ship developing about twenty thousand horse-power on trial and breaking the speed record for naval vessels larger than torpedo boats. The writer was an assistant of Admiral Melville at the time of this design, and he desires here to place on record that all the credit of the success of this type of machinery is due absolutely and entirely to the Admiral himself. He was advised not to use this system by many of his friends of great experience and ability, as well as by some of his older assistants, for whose opinion he had great respect. He felt, however, that the smaller vessels of this system which had been tried, showed that it would succeed, and the circumstances of the case made it the best design.

The results astonished even him in respect to the economy of propulsion, because the vessels made about a knot more speed than either he or anybody else had anticipated. It has been a source of great surprise that triple screws have not been used on other of the large vessels, as it is well known that the Admiral is a sincere believer in the efficiency of the system and has been a constant advocate of it. It is perhaps not desirable at this time to give what the writer believes to be the reason for the opposition to this system, but it is well to note that it has been very largely used in all foreign navies, except that of Great Britain.

It cannot be attempted in a hasty sketch like this to go into all the details of the efforts made by the Admiral for engineering progress in the way of improved materials, increased steam pressures, higher engine speeds, etc. Reference may be made, however, to the numerous experiments carried out with a view to determining the adaptability of oil fuel to the uses of war vessels. Accounts of these have been published and have given a great deal of valuable information, both as to the economic and potential results, and details of apparatus necessary. The latest of these tests have just been published. Mention may be made also of the Admiral's policy of publishing in his annual report each year the designs prepared by the Bureau of Steam Engineering for the machinery of the new vessels authorised by Congress. These illustrated reports have been extremely popular throughout the country and of very great benefit to the engineering profession. A mistaken and cheese-paring economy led to their suppression for a number of years, but in later reports they appeared again.

While realising as thoroughly as any other naval officer that a war vessel is very largely a gun platform and that offensive power is to be given the greatest consideration, the Admiral has been a consistent advocate of the highest practicable speeds for vessels of all types. A case which is at the present moment unsettled, shows that he has not always had the co-operation of all his colleagues in this respect. The most marked case, however, was in 1898, when it was seriously proposed, in asking for bids for three new battleships, to simply repeat the designs of an earlier time, calling for vessels of sixteen knots when all other navies were building vessels of eighteen knots or higher.

At that time Melville was absolutely alone in his fight for the eighteen-knot ships. It is probable that some of his colleagues would have liked to get them, but they were persuaded that delay would result in getting out plans if the attempt was made to get higher speeds. Fortunately for the country, Melville's efforts were seconded most strongly by the general and technical press, with the result that while the Department's own proposition was for the slow ships, the contractors were given the opportunity to submit proposals for eighteen-knot vessels also. To their great credit, be it said, all of them did submit such proposals, and as a consequence the contracts were made for vessels of higher speed.

We may mention, in passing, the two novelties in an engineering way intro-

duced by Admiral Melville at the time of the war with Spain, namely, the repair ship *Vulcan* and the distilling ship *Iris*. The repair ship was not a novelty in conception, for plans had been prepared for one some years before when there was a possibility of war with Chili on account of the *Itata* case, but the *Vulcan* was the first repair ship to be used in warfare, and actually accompanied the fleet. The pages of this and other technical magazines have had detailed descriptions of the *Vulcan*, and nothing further need be said here than that she proved a tremendous success in every way. The distilling ship was not completed until just about the close of the war, so that there was no opportunity to get the benefit of her services; but the precedent has been established, and there is little doubt that in the future distilling ships will be a feature of the auxiliaries to our battle fleets.

Mention ought also to be made of the fact that the usefulness of Key West as a naval base during the war with Spain was due almost entirely to Admiral Melville's foresight and determination. We had had a little machine shop there for years, but it was run down and almost worthless. He had recommended again and again that this be put in a state of efficiency, but was never able to get an appropriation from Congress for that purpose. When it became reasonably certain that there would be war with Spain, Congress gave the President fifty millions to prepare for it. Melville at once took prompt steps to fit out the Key West shops, and was fortunately able to get enough machinery there before the movement of troops began. Although the shops were small and of limited capacity, they rendered a very real service in maintaining the integrity of our blockading fleet.

What has been said thus far relates entirely to Melville's work purely as an engineer, but, as is known to those familiar with naval matters, the engineer-in-chief needs to be not only an engineer of pre-eminent ability, but an executive and an administrator of wisdom and prudence. From the very beginning of Melville's term the question of naval personnel was one of the most important with which he had to deal. The special course for engineers at Annapolis had been abolished and no provision existed for supplying trained engineers for the Navy. Indeed, the outlook for men of exceptional ability was so dark that many of them left the service to go into private life. From the very first he insisted on adequate training for engineers, and also that they should be given proper recognition. Beginning as the representatives of a profession which was looked on as an intruder by naval officers of the old school, and whose actual physical basis on board ship was of minor importance, naval engineers had seen their work increase until, in the minds of unprejudiced people, its importance, if not actually first, was as great as that of any other department. Yet, the status of the engineers was practically what it had been at the very beginning,—a nominal rank, with titles descriptive only of professional duties, and with nothing indicative of the actual position in the military organisation.

The education of young engineers at the Naval Academy had removed a great deal of the personal bitterness which at one time existed between engineer officers and those of the line, but there was still much opposition on the part of the latter to having the engineers recognised as distinctly military officers. Melville's own tremendous personality and the work of his corps under his direction gradually brought about a better state of feeling until, in 1897, the Secretary of the Navy was led to appoint the Personnel Board, composed of representatives of the line and engineers, and presided over by President Roosevelt, then Assistant-Secretary of the Navy. The deliberations of this board extended over a period of more than a month, and under the wise and tactful management of Mr. Roosevelt a report was made to the Secretary, transmitted by him to Congress, and finally enacted into law, which amalgamated the engineers with the line officers and made them what they really are to-day, executive officers. The officer who actu-

ally proposed this amalgamation was Admiral Robley D. Evans (then Captain), but the idea had been suggested by many others even as far back as Secretary Welles' time, during the Civil War. Nevertheless, Admiral Evans deserves the greatest credit for his wisdom and liberality, and it is gratifying to note in this connection that as commander-in-chief of our Asiatic Squadron he is earnestly endeavouring to carry out the provisions of the law to make all line officers competent engineers.

The writer desires to take this opportunity to place on record a statement which he believes is due to the magnificent man whom he is proud to have served as an assistant for many years, and whose friendship he prizes most highly, with respect to his attitude towards the personnel question and its effect upon him personally. During the sessions of the Personnel Board (of which Admiral Melville and the writer were both members) it was decided to recommend the abolition of the grade of commodore, and it looked as if this would reduce the rank of the chiefs of bureau from commodore to captain, because it was not believed at that time that Congress would be willing to give them the grade of rear-admiral. Notwithstanding this, Admiral Melville expressed himself as perfectly willing to be thus a loser for the sake of the general good which would result from the adoption of the personnel scheme.

It has been alleged by some that the Admiral, captivated by the idea of securing a military title, permitted the Engineer Corps of the Navy to disappear as a separate organisation solely that he might be personally benefited. The fact is that the Admiral, like the writer and the great majority of naval officers, believed that the scheme of the Personnel Bill was the best one for the Navy as a whole, and for the Engineer Corps as a part; but while some officers might have expected to be personally benefited by this, there was every reason to believe that Melville himself would actually suffer a distinct loss both in rank and in pay. That the rank of bureau chiefs was made rear-admiral when the bill came to be considered by the Naval Committee of Congress, is something with which Admiral Melville had absolutely nothing to do, although it is very probable that the loss of rank to him, if chiefs of bureaus had been made captains, had great weight with the Congressional committees.

Another point, also showing the benefit to the service as a whole which his splendid personality has been, is in the provision of the Personnel Law that officers who had served during the Civil War with a creditable record should, when finally retired, have the rank of the next higher grade. It is probable that relatively few except the members of the Personnel Board know just how this came about.

At one of the meetings, toward the end of the deliberations, Admiral Evans pleasantly referred to the probability that Melville would shortly be a rear-admiral. The writer called his attention to the fact that from the position on the amalgamated list of captains which would be taken by Melville, it was almost certain that he could never reach the grade of rear-admiral by lineal promotion. Admiral Evans then said:—

"Mr. Secretary, I feel this is a great misfortune, and we certainly ought to do something to show our appreciation of Melville and his work. I suggest that if he cannot become an admiral by lineal promotion, we at least arrange that he shall have the rank of admiral when he retires."

This met with unanimous approval, and it was at first intended that this provision should apply only to officers of the old Engineer Corps. Melville, however, called attention to the fact that some line officers, notably Admiral O'Neil, Chief of the Bureau of Ordnance, who had entered during the Civil War, would also fail to reach the grade of admiral by lineal promotion, and it was then decided to have it apply to all officers of the new line. When the bill came into Congress, the Congressional committees arranged the provision to apply to all officers who had served during the Civil War. It is thus very

evident that had it not been for the great esteem in which Melville was held by his colleagues, this great benefit to Civil War veterans would not now exist.

It is not out of place to remark here that the recent reorganisation of the personnel of the British Navy is along lines almost identical with those which had previously taken place in our own, and there can be little doubt that this was due very largely to our taking the first step. As already stated, the result in our own Navy very probably came about mainly through Melville's own tremendous personality and magnificent work, so that we can feel that he has been a main factor in this great change in two of the great navies of the world.

It remains to say a few words about the man as a man, apart from his work as an engineer and as an administrator. It has been said by many who have met him that he is one of the old Vikings who has reappeared a millenium after the others had gone. One has only to see him to realise the frankness and sincerity of the man, and one can be associated with him for only a short time to find that he is one of the most lovable, kind-hearted, and considerate men whom one could ask to have as a chief.

The writer well remembers the enthusiasm which he inspired in the young men who were his assistants when the writer first went on duty with him shortly after he came into office. There was absolutely nothing that we would not have done for him, and we counted it a pleasure to work over-time if he deemed it necessary. This ability to inspire loyal affection and devotion is one of the most remarkable characteristics of this man who is remarkable in so many ways. His heroism and undaunted courage under the most trying circumstances are known to all the world, but the lovable side of his character can naturally be known only to those who have the privilege of intimate friendship.

He is a keen judge of character and ability and has made very few mistakes in selecting his assistants. Having selected and proved a man, he then gave him his complete confidence and left him very largely to do his work, with gentle oversight and suggestion when necessary or when asked for. Further than this, there have been few cases of the chief of a great office who was so ready to give credit, not only in conversation but in print, to the work done by his assistants. Being a big, broad-gauge man himself, he has no small vanity which demands that all the credit for the work of his office shall come to him personally; but he has always been glad to see his assistants get all the credit they deserve.

Admiral Melville's case is one of the few exceptions which emphasise the wisdom of the rule of retiring officers from active duty when they reach the age of sixty-two. He is to-day as hale and hearty and as vigorous mentally and physically as he was at fifty, and it is a distinct misfortune to the Government that the operation of age limit retires him from further active service in the position which he has filled so splendidly. However, it has become Government custom in recent years to call on retired officers of great ability for occasional special service, and undoubtedly the Navy Department will frequently avail itself of the Admiral's talents.

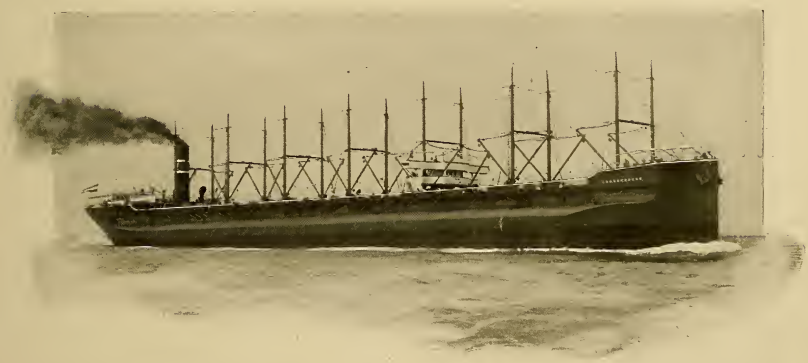
In thus placing on record a brief and very incomplete sketch of the official career of this great man in his high office, the writer knows that he is voicing the sentiments of all the men who have had the privilege of serving as assistants to Admiral Melville, and also of the large body of engineers who have been brought in contact with him. He believes also that engineers generally feel that his magnificent record as engineer and administrator is a just source of pride to the engineering profession as a body. Time was when engineers were content to do their work without much thought of receiving special credit for it, but "times change and we change with them," and this has become the age of the engineer. We feel, therefore, that as engineers we all have a right to take personal pride in the splendid personality, the great success, and the monumental work of Admiral George Wallace Melville, the engineer.

Current Topics

It has been demonstrated that much the larger share of trouble caused by imperfect contacts in switchboard connections in telephone exchanges can be prevented by proper ventilation of the operating rooms, and that implies thorough cleansing of the air entering them. Many experiments have been tried in the way of dry-cleaning by filtering through screens of wire and cheese-cloth or cotton-batting, but all such devices require frequent renewal, sometimes at considerable trouble and expense. By continued use any filter of this character must deteriorate and eventually become clogged, and in order to avoid the results of neglect it ought to be practically automatic. This point is essential in an air-cleaning system. In the case of one large telephone company very satisfactory results have been obtained by passing the air supply through a fine spray of water and afterward precipitating the moisture with the collected impurities and discharging it into the sewer. The water which is taken up at high velocity and held in mechanical suspension is extracted by centrifugal force by passing it through a series of tubes in which spirals are so placed as to give the air a whirling motion, causing the suspended particles, which are heavier than the air, to be thrown outward and brought in contact with the tubes, from which they flow through perforations to a drip-pan below. The washing process imparts about 70 per cent. humidity at a temperature of 70 degrees Fahr. in the operating room. This is considered the most desirable for health and comfort, and avoids the excessive dryness sometimes resulting from other systems of heating and ventilating. Moreover, in summer time, with the temperature outside at 80 degrees Fahr. and with the normal temperature of the city water, the air delivered to the rooms can be readily reduced to 70 degrees. This is a supplementary advantage which must appeal at once to sufferers from extreme summer temperatures everywhere, and with the growing knowledge that such an advantage is available the insistence will undoubtedly come that buildings should be kept cool in one season as well as warm in another.

The cargo steamer is built to carry and to make money, and with the steady decline in freights and ever-increasing competition, she must be first and foremost an economical ship. To produce such a carrier, some of the best brains in the shipbuilding industry have la-

boured. A roomy ship, bluff of form, designed to carry a large deadweight on a small net register tonnage, fitted with big hatches and numerous winches, and provided with abundant ballast and engines capable of a moderate speed on a small consumption of coal,—these, in the main, are the features which distinguish the modern cargo steamer. A vessel which embraces these characteristics to an extraordinary degree, and is, besides, perfectly adapted to the particular trade for which she is intended, is the new British-built ore-carrying steamer *Grangesberg*, illustrated on this page. When she sailed out of Sunderland a short time ago on her trial trip, it can safely be said that a more remarkable looking ship never was seen on the Whitley "measured mile." The banks of the Wear were lined with people to see her off, and at Tynemouth and Whitley, promenaders stared in wonderment at the "nautical nightmare" which steamed tangibly before their eyes. The *Grangesberg* has many peculiarities. Although a big vessel, with a deadweight capacity of 10,300 tons, she is single decked, and her hold is divided into twenty-four compartments, which, together with a powerful longitudinal girder running from the stem to the engine-room bulkhead, make her an exceptionally strong ship. But it is in her upper works that the *Grangesberg* presents her chief points of interest to view. Her long sweep of turret deck, broken amidships only by the bridge and charthouse, is fitted with fourteen masts,—stump masts, placed in pairs abreast of each other, each bearing two derricks, and all of them bound together by thwartship steel girders, and longitudinal steel cable stays. If aloft the ship is a perfect forest of masts, her decks are a bewildering maze of hatches and winches, for she has twelve of the former and twelve of the latter, double-ended. For the rest, it may be said that she carries her 10,300 tons on a draught of 22 feet 8 inches, has her engines and boilers aft, and along the sides of her turret there range twenty-four specially designed collapsible platforms, capable of being run out over the sides of the ship or being snugly folded up and secured on the turret.



THE NEW CARGO CARRIER "GRANGESBERG"

THE *Grangesberg* was built to the order of Messrs. W. H. Muller & Co., of Rotterdam, and is intended for carrying ore from the Swedish mines of Grangesberg to Rotterdam, the ore being put on board at Oxelosund, in the

Baltic. In loading, the ore is simply poured from shoots into the twenty-four compartments into which the hull is divided. In discharging, the gear above described comes into operation. The platforms are run out, four derricks to each hatchway work in conjunction with the twelve double-ended winches and raise the ore out of the hold over the platforms and into lighters with great rapidity, the whole 10,300 tons, in fact, being discharged in 34 hours. The vessel was designed by Mr. Charles Doxford and Mr. John Gravell, of the Bureau Veritas, with which corporation she is classed, her building being supervised by Mr. R. H. Harkness, of the Bureau Veritas. Her engines are of the triple-expansion type, built by Messrs. Wm. Doxford & Sons, Ltd., of Sunderland, with cylinders 26, 43, and 72 inches in diameter, by 51 inches stroke, working at 180 pounds pressure. She is 440 feet long by 62 feet beam by 29 feet depth of hold. The amount of work this vessel will do, and the quantity of ore she will carry and put overside in the course of a year, are noteworthy, the figures comparing favourably with those reached at some of the Great American Lake ports, where wonderful performances in the way of loading and unloading ore cargoes have been the rule for years past. From Rotterdam to Oxelosund is a run of 4½ days at 10½ knots. This run the *Grangesberg* will do under water ballast, of which she carries 3,500 tons. Arrived at Oxelosund she will take in her 10,300 tons of iron ore by shoots in little more than a day, and, departing immediately, will return to Rotterdam in about the same time. In 34 hours after arrival at the Dutch entrepot, she will be emptied and ready for another trip. After making allowances for bad weather, delays, cleaning and repairs, etc., she is estimated to make 24 round trips a year, in the course of which she will carry and deliver 200,000 tons of ore. If after doing that, or anything like it, she does not prove herself *in excilsis* an economic carrier and pay good dividends, both her owners and designers will be disappointed in their calculations.

In the design and construction of very large bridges three factors must be taken into account,—permanence, rigidity, and, last but not least, economy. The last is of great importance because of the heavy interest charges due to the enormous capital sunk in such structures, which, when erected by communities, increase taxation for very long periods. The next important point to be considered is the permanence of at least those parts which form the main carriers and upon which the life and safety of a bridge depend. Great rigidity cannot be neglected, but so long as flexibility does not produce wear, distortion, or excessive or indeterminate stresses, it is of lesser importance. There are three types which are available for very large bridges. Two of these,—the wire cable and the cantilever types,—have been tried by actual service. The third,—the stiffened chain-cable suspension bridge,—has hitherto not been used for spans above 800 feet long.

At present, however, a proposition is under consideration for the building of such a bridge across the East River at New York to further facilitate communication between the boroughs of Manhattan and Brooklyn. Close to the site of this proposed structure there are now in existence two wire cable suspension bridges, each of about 1600 feet span, the older of which has been in actual use up to its maximum carrying capacity since 1883, without showing any signs of weakness or deterioration in any of its important parts, although some minor details developed defects because of neglect and lack of inspection. In view of the satisfactory service rendered by this bridge and the admitted perfection of a second one of similar type, to be put into use within a short period of time, the proposition to construct the third bridge different from the other two in that the main suspension cables shall be made of eye-bar chains, these to take the place of wire cables, is worth noting. It happens that the dimensions of this bridge, although less than those of the

other two, the span being 10 per cent. shorter, are such that it will require eye-bars larger in every way than any that have ever been constructed; in fact, there is no machinery in existence anywhere capable of making them. Moreover, there is no machine of a capacity more than one-half that necessary to properly test such eye-bars after completion. It may be admitted that material of proper quality can be obtained, but this does not alter the fact that the building of such a bridge would be simply a gigantic experiment for which there is no precedent. In other lines of engineering, experience obtained from increasingly larger structures have been the accepted basis for still further increase in dimensions; in this case no such experience is available. It is proper, to begin with, to inquire into the probable permanence of a chain cable bridge, for if this is not assured in a structure intended to stand for centuries to come, its construction had better be abandoned. All engineers know that chains of all kinds wear out from two causes,—abrasion and corrosion at the connecting points between the links. Under the most favourable conditions,—that of flat bars, packed closely side to side and connected by pins,—it is impossible to prevent water from reaching the pins and the holes in the bars or links through which they pass; in fact the capillary spaces between them will draw moisture into them and expedite corrosion. If corrosion thus formed would not be disturbed, we may admit that further deterioration would be slow because of the protecting coating of oxide thus formed. However, a chain in a suspension bridge, especially when supported by and passing over oscillating towers, as is proposed in this structure, must necessarily change its shape under the effect of both temperature changes and varying loads. Such change of shape can, however, take place only at the connecting points between the links, and hence will there produce constant motion. The corrosion already existing will be disturbed by this, new surfaces will be exposed to moisture, and, as a result, rapid and increasing corrosion will be encouraged. To prove that this is the condition existing in all pin-connected structures, all that is necessary is to examine some of them, no matter where they may be found. Another action produced by changes of shape of chains, and due to the intense pressures between pins and the surfaces of the pin holes in the eye-bars, is the generation of great transverse bending stresses in the bars. Because of the known existence of these secondary stresses, pin-connected bridges have never found favour in Great Britain and continental Europe, and rivetted structures have there been built almost exclusively.

From this it will be seen that in course of time the chain will have to be replaced, even if it be after only a century. And when this becomes necessary, what will posterity do about it? It is a well-known fact, on the other hand, demonstrated by a number of large wire-cable bridges, that the wires in the cables can be protected absolutely against corrosion. In case, however, neglect has allowed some corrosion to occur in certain exposed parts, it is an easy and not at all a costly matter to cut out corroded wires and replace them by new ones, made to work in harmony with the others; in fact, this has repeatedly been done.

When, again, we examine the rigidity of suspension bridges, it will be found that this depends upon two factors. The first is the elasticity of the material; the second is the amount of play existing at the connecting points. As to the former, it is to be noted that all steels change their length almost equally under equal changes of loading, whether they be high or low-carbon steels. The amount of play at the connecting points, however, is an indeterminate factor because it depends upon accuracy of workmanship and careful inspection. This

play in pin-connected suspension bridges is of great importance, because the stresses in most members of the stiffening trusses are reversed, due to their changes of position and elevation under changes of temperature and loading. It must be remembered that these trusses must be designed for a mean position, the floor rising above and dropping below this under changes of temperature. Hence, during such changes the play at connecting points becomes a very important matter. It is well known that friction connections can be made between a wire cable and its stiffening trusses which will hold just as firmly as any pin connection. Such friction-clamps and connections are in extended and varied use in many places, and their rigidity and permanence in position are well-established facts.

One claim, made for eye-bar chains, is, that the suspender or brace-connections would bend the wire cables, thus producing excessive stresses in them, but that they would not so bend chain cables. It is also denied that a wire cable has transverse stiffness of importance. But in all wire bridges, bending of the cables at connections is unknown, otherwise there would be apparent cracking of covering and paint, which has never yet appeared in any case. Moreover, a bundle of wires 15 or 18 inches in diameter, squeezed together and then entirely wire wrapped or banded at short intervals, is known to be a body of very great lateral stiffness, and would resist, without bending, a very considerable transverse force. The mere denial of such stiffness in face of well-known facts to the contrary ought not carry weight, and there is thus no reason why the stiffening trusses of a wire bridge should be heavier or stronger than those of a chain-cable bridge. All those who have carefully examined large existing cantilever bridges, moreover, are perfectly aware of the fact that they are extremely flexible and change their shape to a very considerable extent under varying or moving loads.

When the question of economy of construction and erection comes up for consideration, it is to be borne in mind, first of all, that wire made for suspension bridges has a yield point over 190,000 pounds per square inch. The best steel obtainable at present for eye-bars has a yield point of not more than 50,000 pounds per square inch. As the yield point is that factor upon which the allowable unit stresses in materials depend, because at that point the material begins to change its shape permanently, and not until this is reached, it is apparent that if the loads placed on the structures never exceed one half of these stresses, structures of the two kinds of material will be equally safe against permanent distortion. It must be admitted that a structure permanently distorted is permanently ruined. Hence, the main supporting members of two structures composed of such materials must have sections in the ratio of 95 and 25. Therefore, wire cables will weigh about one-quarter as much as chain cables without mentioning the extra weight of eyes and connecting pins necessary with the latter. Moreover, anchors to hold the cables in position and towers sufficient to carry them and the loads will bear similar ratios of quantities of materials. The weights of the stiffening trusses and floor system may be considered to be about equal. From this it will be seen that the wire cable bridge must be very much more economical than one having chain cables, even though the wire cables might cost twice as much as the eye-bar chains, delivered at the site of the bridge, but not erected.

This brings up for consideration one other point, namely, that of time and cost of erection of cables, because the erection of towers, anchorages, floor and stiffening trusses will be about the same in both cases, with an advantage in favour of the wire bridge in the first two items. It is pretty well known how much time and money is required to erect wire cables of long

spans. Nothing is known, however, about these points in the case of chain bridges of similar dimensions. It is known that temporary footbridges for erecting wire and chain cables will be required in both cases, and that those for the latter must have five times the strength of those used for the former, as the loads to be carried during erection will be five times as great. The only evidence on hand to show what time it will take to erect chain-cables is to be found in the case of the Budapest bridge, now building, which has already been delayed two years through the use of such chains, and this structure is of only half the length of that now proposed for the New York bridge with its 1470-foot span. The question of the propriety of making an experiment of the building of a bridge of such size and enormous prospective cost,—and that the adoption of a chain-cable design would be,—is one of general and not simply local interest. For the present the choice of a design for the New York bridge yet remains to be made.

THE electric theory of matter has received a strong impetus at the hands of Lodge, Thomson, Crookes and others, especially since the discovery of the radio-active substances, such as thorium, radium and others. This theory assumes that the material atom is made up of a large number of so-called electrons, the number depending on the density of the substance. Thus, for instance, it is assumed that an atom of hydrogen is made up of about 700 electrons, a mercury atom of about 140,000 electrons, and a gold atom of about 137,200. The different known elements, therefore, are made up of different groupings of electrons. The theory further assumes that these electrons are in stable orbital rotation around one another, the whole being held together by mutual attraction, their orbits being as large relative to the size of the electrons as the orbits of the planets of the solar system. With such a theory as this it was to be expected that modern alchemists would promptly seize the opportunity of bringing about a rearrangement of the electrons so as to produce from one element a more valuable one. This expectation has been realised in the person of a Philadelphian inventor or experimentalist who claims to have already brought about a transmutation of silver into gold. He selects silver for the transmutation because of the approximate similarity of these two elements chemically considered. The process by which the transmutation is accomplished is chemical and electrical, of course. The inventor admits that the elementary forces of nature in combination and decomposition are well-nigh irresistible, and, therefore, to transform one atom into another it is necessary to destroy the inductional capacity of the electrons by bringing them to a condition of temporary inactivity or torpor. The electrons can then be segregated, he claims, and forced out of their previous correlation, and then be reassembled in any desired grouping. The inventor has no difficulty in showing prospective investors in the stock of the company which will probably be organised that the net profits in transforming one million ounces of silver into a similar amount of gold will be over sixteen millions of dollars, the cost of transformation being only 17 per cent. of the value of the product. This scheme, it will be seen, is quite as reasonable as, and far outstrips in calculable profits, the Keeley motor enterprise, the home of which, by the way, was also in Philadelphia.

MOST of those who have taken part in recent discussions of that popular topic,—the training of the young engineer,—have seemed to agree in minimising the value of theoretical as opposed to practical knowledge. A word from the opposite point of view may, therefore, not be out of place. It is true, of course, that the large majority of commercial designing is done by the aid of cut and dried formulæ, and that it would be useless waste of time for an engineer to attempt to work out every-

thing from fundamental principles. Neither he nor his employers would gain anything from this. In considering the question of the training of students, however, the main point is not so much what to teach them in order that they may be useful in their field with the least amount of actual practical experience gained after leaving college, but rather what they should learn in order that ultimately they may be the most valuable. If all we expect of a young man is that he should be able to design rapidly and accurately,—in fact, that he should be acquainted with all the existing methods, both engineering and commercial,—then let us send him directly to the factory or to the shop; he will there reach his goal much more rapidly than by attending college. But that is not the aim of a school, and those who would advise the further curtailing of theoretical instruction during the school course seem to entirely overlook this point. They overlook another point, and a very important one, too.—that the student himself generally takes the same shortsighted view of the case.

THERE is experience to show that students are only too well acquainted with the existence of handbooks, of Lloyd's and of Board of Trade rules, and the like, and that the difficulty is not to induce them to make use of these shortcuts, but to get them to devote even a small part of their attention to the rational foundation of these rules. And such a foundation exists for all of them. Many of the most valuable formulæ are empirical, it is true, and based on observation. But it must not be forgotten that the most elaborate series of observations would lead to no useful results unless based on scientific principles, with a definite point in view. The man who has mastered the theory of a formula will easily learn its practical application, and there need be no fear of his preferring the long to the short process when the proper time comes. But he who knows only the rule and not the basis of reasoning will always be limited. An instance is recalled where the entire staff of a large draughting office was unacquainted with the theory of a formula which they had been using for years. Upon working out the mathematics of the problem they were not only found to be quite simple, but also to suggest a very obvious and rather useful improvement. It had not been found previously, simply because apparently it was not considered the proper thing for an engineer to try to investigate the theory of well-established formulæ. That would have been a waste of time! Many such cases no doubt exist. It is to train men who are capable of discovering these improvements that young men are sent to universities, and not to train men who are capable merely of following in the footsteps of others. The most successful engineers, and those who will do most for the science, will always be those who have a sound practical knowledge based on a thorough theoretical foundation. To such men, men like Reuleaux, and Rankine, and Unwin, and Seaton, and many others, we owe the greater part of our present engineering knowledge.

PHOTO BY C. M. BELL, WASHINGTON, D. C.

REAR-ADMIRAL CHARLES WHITESIDE RAE

THE NEW ENGINEER-IN-CHIEF OF THE UNITED STATES NAVY

SEE PAGE 560

CASSIER'S MAGAZINE

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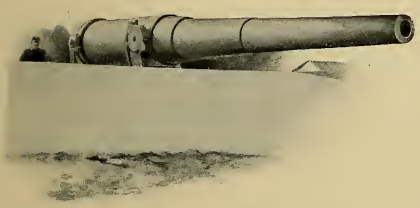
LATE DEVELOPMENTS IN ORDNANCE AND ARMOUR

By John F. Meigs Ordnance Engineer of the Bethlehem Steel Company

About two years ago, at a meeting of the Society of Naval Architects and Marine Engineers, Mr. Meigs read a paper in which he reviewed the progress made in connection with ordnance and armour during the decade immediately preceding. With slight changes, this paper is eminently apropos at the present time, and, through Mr. Meigs' co-operation these changes have been made in the following pages. The material thus, in its present shape, reflects current practice and tendencies. The illustrations were specially selected for publication here.—THE EDITOR.



TEN-INCH GUN ON A DISAPPEARING CARRIAGE, FIRING POSITION

DURING the past twelve years the developments in armour plate have consisted in, first, the introduction of nickel in the armour; second, the adoption of the super-carbonising process invented by Harvey; and, third, the perfecting of this super-carbonising process by Krupp. Parallel with these improvements in armour plate, whose tendency, or rather the tendency of the latter two, has been to produce armour with a very hard outside face, the velocities of projectiles have advanced. From a purely rational point of view this would appear to be unreasonable, because hard armour is best attacked by heavy projectiles, which, if the size and weight of the gun remain constant, would mean a lowering of velocities. In other words, hard armour which may be cracked, is best attacked by heavy projectiles, and comparatively soft armour by light, fast-flying shot.

In the period under review the advance in the resisting power of armour has been very material. The advance made by the introduction of nickel and by the adoption of the Harvey surface-hardening process, which were brought in at about the same time, added probably quite 25 per cent. to the power of armour plate of fixed thickness to resist penetration. The adoption of the Krupp process probably added another 10 per cent. to the resisting power of armour plate, and also added very materially to its power to resist cracking. It is, perhaps, not too much to say that the armour of to-day has 40 or 50 per cent. more power to resist penetration than that of ten or twelve years ago of the same thickness. Its power to resist cracking is very difficult to measure numerically. This power, however, is very greatly increased, as much because of the better methods of melting and

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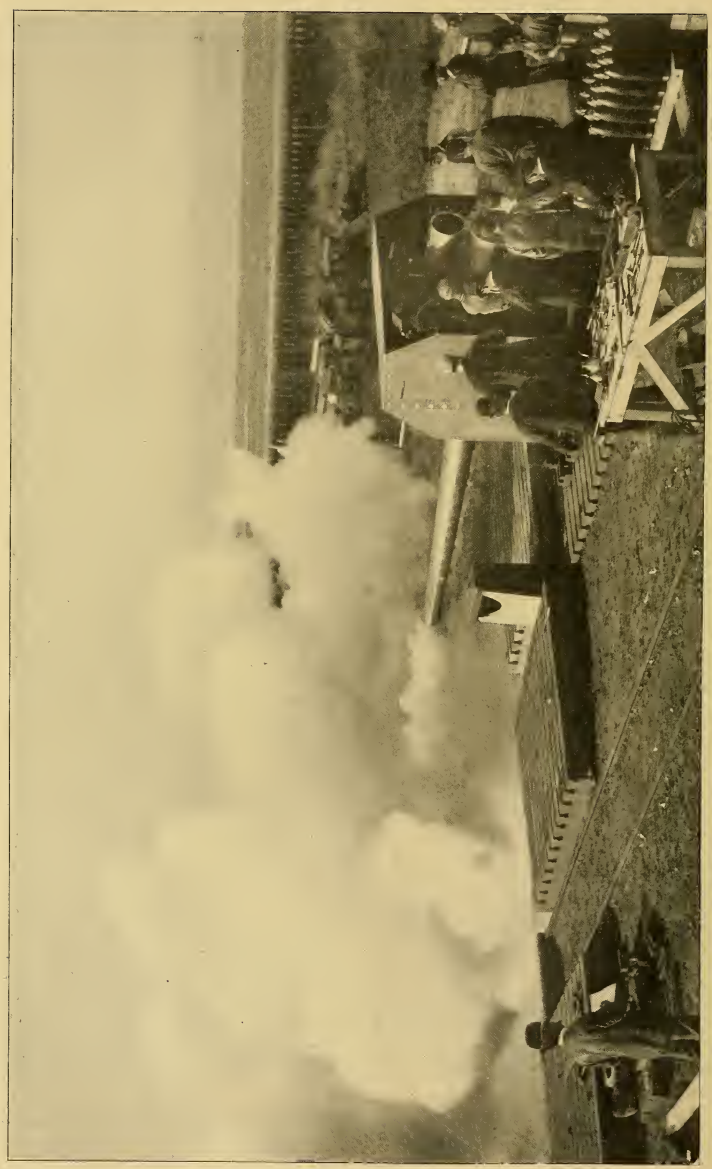


FIRING A SIX-INCH GUN AT THE PROVING GROUNDS OF SIR WM. G. ARMSTRONG, WHITWORTH & CO., LTD., NEWCASTLE-ON-TYNE

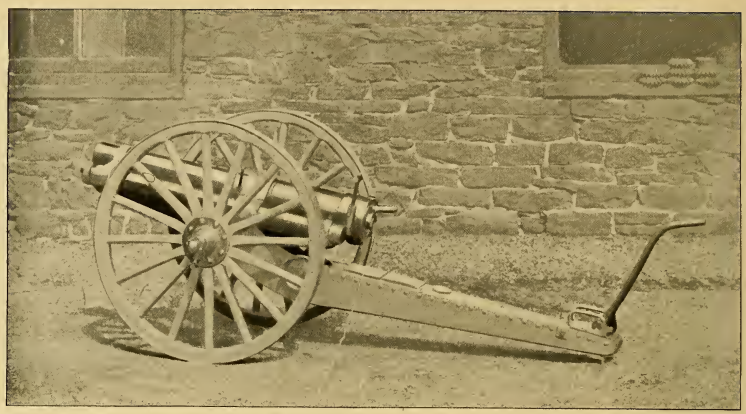
forging large masses of steel as for any other reasons. It seems now almost impossible to crack well-made armour plates under conditions approaching those usual in reception tests. Their surfaces are spalled for an inch or two in depth, and the tough back of the plate is very resisting to cracking effect. In a word, when comparing the armoured ship of to-day with the ship armoured twelve years ago, say, with the same thickness of plate, we find the former to have an enormous superiority.

The same degree of superiority is not found in the gun itself. The guns of a fixed calibre are longer and heavier than they were, and the powder is better than it was; but, as stated, the gun itself, though shaped differently, has not improved from improvement in quality of material so much as armour plate. Ten years ago a 6-inch gun weighed about 11,000 pounds, while now it weighs from 17,000 to 18,000. The former gun gave barely 2000 feet muzzle velocity with the brown powder then in use, while the later gun, with its charge of smokeless powder, will give 3000 feet or more, and thereby its energy is more than doubled.

This increase, however, it will be noted, is largely because the gun is heavier than the old 6-inch gun. The advantage which is most marked in the past decade in ship's guns, or, to use the more general term, in guns of position,—that is, guns that are not moved from the place where they are set,—is in rapidity of fire.

Ships of war have fired ten shots from a 6-inch gun in one minute, at a range of about 1500 yards, at a target 15 feet high, and struck it every time. Also 12-inch guns in turrets have averaged two hits in three minutes upon similar targets. In connection with this also may be mentioned the fact that the United States Artillery have fired thirty shots from a 10-inch gun on a disappearing carriage with one detachment of gunners, in one continuous string in twenty-seven minutes. Such feats a few years since would have been thought impossible, and, in fact, many people with whom I have conversed will not believe what I have stated to be a fact, but the reports in the newspapers are of such a nature that I myself believe them to be true. No doubt the ammunition was close by, or it is possible that the ammunition supply arrangements may have been extremely good and that the ammunition may have been brought from the magazine. This is unlikely, however, and in the statement that I have seen this is not said to have been the case. The actual trial of how many complete rounds of ammunition can be delivered to each gun in a ship in a certain period of time would appear to constitute as important a datum regarding her efficiency as her record on the measured mile. It would depend, of course, upon her structural arrangements and upon the skill of the ammunition passers.

No doubt, also, the ship's course was carefully selected in such a way as to blow the smoke away from the gun, for although powder is now called smokeless, the heated gases coming from the gun make it impossible to aim properly until they have blown away, and, if blowing towards the firer, they would hurt his eyes so that he could not make good practice. We hear, also, of guns, whose projectiles weigh 350 pounds, being fired three or four times a minute. These things are no doubt true, in at least a limited degree, and constitute a very marked advance in gunnery; for, while it would not be possible to fire guns many minutes at eight or ten rounds a minute, both because the crew would become exhausted and because the gun and other parts would heat, yet the fact that this can be done for a short time, when it becomes necessary, is a matter of great consequence. This end has been reached by so building the gun and carriage and so using them that the gun is kept always pointed, and is fired as fast as it is loaded. It may thus be said that the speed is that to which the loading can be pushed. This increase in speed of fire immensely heightens the importance of so building ships that ammunition can be passed quickly to the guns. The gun-pointer simply keeps the gun aimed all the time, and



A THREE-INCH MOUNTAIN GUN MADE BY THE BETHLEHEM STEEL CO., SOUTH BETHLEHEM, PA. WEIGHT OF PROJECTILE, 12 LBS. MUZZLE VELOCITY, 1200 FEET PER SECOND. WEIGHT OF GUN AND CARRIAGE, 724 LBS. GUN AND CARRIAGE BREAK UP INTO FOUR LOADS OF APPROXIMATELY 200 LBS. EACH, WHICH CAN ALL BE LOADED ON THE SAME TYPE OF SADDLE AND CARRIED BY FOUR ANIMALS

fires it whenever it is loaded and as quickly as it is loaded. The adoption of measures of safety whereby he, standing half way from the breech to the trunnion of the gun, and with his back to the breech block, cannot fire the gun unless the breech is properly closed and the man handling it out of the way, are details of manufacture which have been mastered.

While it is very difficult to say at what range modern ships will fight, yet it would appear that this matter must be settled before any conclusions can be reached with regard to the kind of guns to be placed in ships. The ship that can control range can outclass the other. It is necessary to determine to what range ships will usually come before determining upon their batteries and armour.

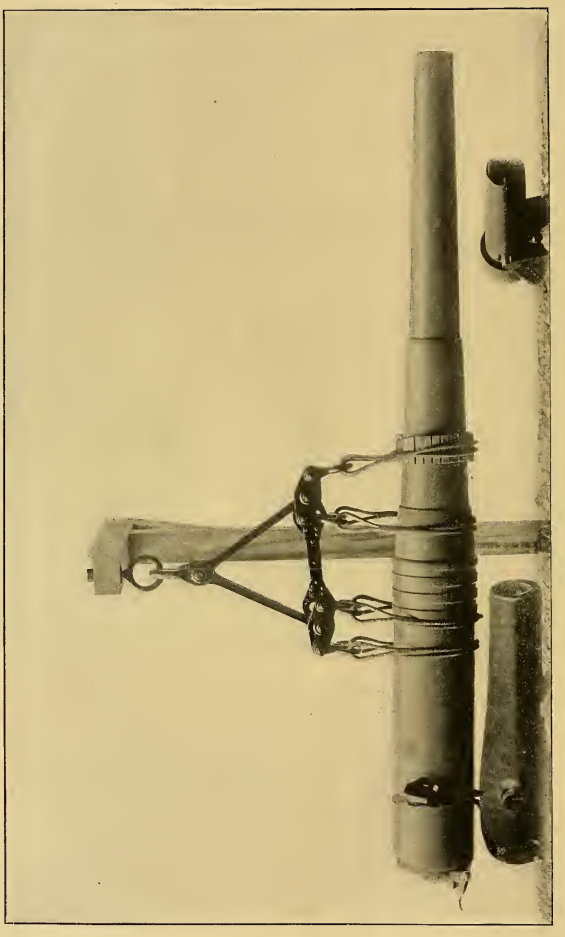
There is much difference of opinion in regard to the range at which the modern gun is effective. Possibly this comes from a neglect to appreciate the circumstances of the use of the gun, rather than the accuracy of the gun itself. The gun is itself very accurate, but the circumstances of its use are much less so. The changes in velocity, due to changes in powder, cause some variation in the range of the gun; but the greatest difficulty consists in the absence of correct knowledge of the range, and, in guns in ships, in the continual motion of the ship,—both the rolling motion and the swing, when the ship is turning through an angle. The writer's impression is that those who have witnessed a good deal of firing from guns in coast fortifications think that a ship would be in great danger from the guns of a fort in direct fire at 8000 or 9000 yards, and this presupposes that the range is accurately known, as it usually may be in a fort. The writer should think, however, that such great accuracy would be attained only when the firing is very deliberate, and when such elements as the muzzle velocity due to the powder in use are accurately known. In a ship gun, where the range is rarely accurately known, and where the ship is usually moving, accurate practice cannot be made at so great a distance as 8000 yards. The writer believes that most naval officers are of the opinion that with their guns, and in reasonably smooth water, they can make fair practice at 3000 or 4000 yards. The writ-

er's own belief is that this is too great an estimate. At 3000 yards range with a target 15 feet high, when a gun is rolling at an angular rate of one degree per second, which is a fair rate only, the prolongation of the line of sight of the gun would sweep across the freeboard of a ship 15 feet high, which would include all the vulnerable part of the ship, in somewhat less than one-tenth of a second. This is a period of time too small to be appreciated by a man's nerves, and, indeed, the accuracy of operation of the firing apparatus of the gun can hardly come within this limit.

THE GUN OPPOSITE, PACKED ON A SADDLE FOR TRANSPORTATION. THE OTHER LOADS ARE THE SLIDE, WHEELS AND AXLE, AND TRAIL AND SHAFTS

It is usual to assert that naval guns stand in greater need of high velocity than land guns, in order that the trajectory may be flatter and the gunner independent of the range at great distances. At present, for practical purposes, the trajectory is a straight line,—having regard to the height of the broadside of the ship,—for about 1500 yards in length. By insisting, however, upon what is known as "power" in guns,—that is, the use of elongated and fast-flying projectiles rather than those which approach a rounded form and move with lower velocity,—much is necessarily lost in smashing effect. The shell charges also become smaller and the mine effect of the shell becomes less, and the damage to constructions that are hit becomes less. The shot of the old-fashioned 9-inch smooth-bore guns weighed 90 pounds, while that of the modern 6-inch rifle weighs 100 pounds. For anything that it can penetrate, the former constitutes a more dangerous projectile than the latter. Against the upper works of vessels the old round shot is by no means to be despised.

This all raises the question of what calibre of gun the designer of a warship will put in. He has a certain weight to put into battery, and the question comes to him at once:—Having 100 tons to dispose in guns and gun carriages, shall it be put in so many 8-inch guns or in so many 6-inch guns? Roughly, the weights of guns vary with the cube of the calibres, so that for every 8-inch gun you can have eight 4-inch guns. As the 4-inch gun fires a good deal



20-inch Rodman Smooth Bore.
Weight, 116,000 lbs. Projectile,
Round shot, 1000 lbs.

10-inch Parrott Rifle.
Weight, 26,000 lbs.
Projectile, 300 lbs.

THE U. S. ARMY 16-INCH RIFLE. WEIGHT, 358,400 LBS.; PROJECTILE, 2370 LBS.
THE NICKEL-STEEL FORGINGS FOR THIS GUN WERE SUPPLIED BY THE BETHLEHEM STEEL COMPANY

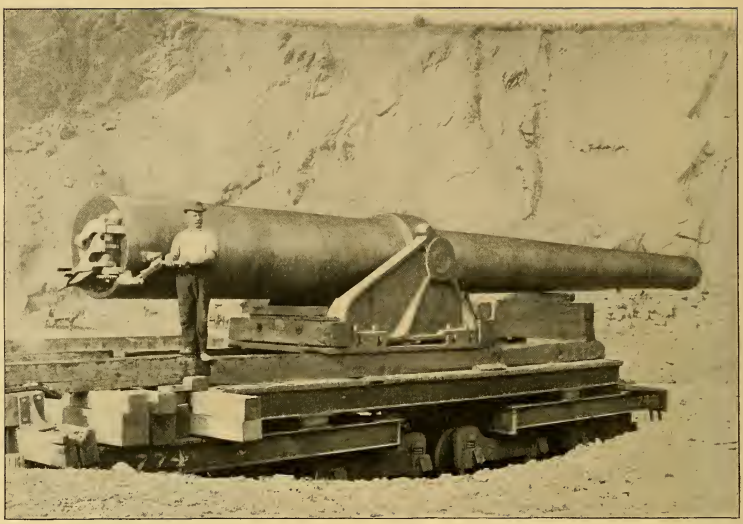
faster than the 8-inch, the weight of metal and of bursting charge thrown by the battery of light guns would considerably exceed that thrown by the heavier ones. The weight of a single discharge from a battery of fixed weight of any calibre, would remain about the same, of course. These, it seems, are the great tactical questions in regard to guns: --First, having a fixed system of guns, —that is, having guns of differing calibres in which the dimensions are about proportional to the calibres,— what size guns shall we use ?. And, second, there is the other question: —Is the system right? That is, should 8-inch guns weigh what they do, or should they weigh more or less? Or, to put it in another way, are we satisfied with present weights of guns, or do we want more velocity in a gun of fixed calibre, and are we willing to accept the increased weight that must be given to the gun to get this?

Much discussion is going on now in regard to the substitution of 7-inch and 7.5-inch guns for 6-inch guns on the broadsides of battleships, and, while everybody must be desirous of increasing to the utmost the size of the guns, and, consequently, their destructive effect, it must be remembered that this inevitably makes the weight carried heavier, and limits the speed of firing. It has been generally asserted that guns cease to be rapid-fire when increased beyond 6 inches in calibre. Even 6-inch guns must have their cartridges separate from the projectiles, and, as the projectile weighs 100 pounds, it is about all that one man wants to put into a gun quickly when standing on the deck of a rolling ship.

There are many minor improvements which have been introduced in the use of guns, as, for instance, the almost general adoption of telescopic sights, which give greater accuracy of fire, the use of electric firing, which fires the gun more quickly when the sights are on, the use of automatic ejectors for the primers, and improvements in fuses. Also, high explosives have come to be used very generally in shell. These explosives are usually of the picric acid order. Many believe that they are quite as safe in shells as the old black powder, and, as they certainly break shells into a larger number of parts than the older explosives, it would appear that they will be more widely adopted in time.

Caps also have been used on the point of armour-piercing projectiles, and these are becoming universal. Many theories are advanced as to why they help a shot through an armour-plate; but of the fact that they do so help it,

CAPPED ARMOUR-PIERCING SHELL



THE 18-INCH GATHMANN GUN FOR FIRING HIGH EXPLOSIVE SHELLS. WEIGHT OF PROJECTILE, 2000 LBS. WEIGHT OF GUN AND MECHANISM, 134,000 LBS. LENGTH OF GUN, 44 FEET. GREATEST DIAMETER, 45 INCHES. MUZZLE VELOCITY OF PROJECTILE, 1930 FEET PER SECOND

there is no doubt whatever. It is said that they are least effective in oblique fire, and, while this may be so, it is yet a thing very hard to demonstrate, as the penetration of all armour-piercing projectiles falls off very quickly when the shell does not strike fairly point first. The cause of this seems to be largely that the whole back end of the projectile, upon striking a plate obliquely, is wrenched off, and the very second that a projectile, when striking an armour plate, begins to go to pieces, that second it is done for, and its chance of doing any material harm to the armour becomes nil.

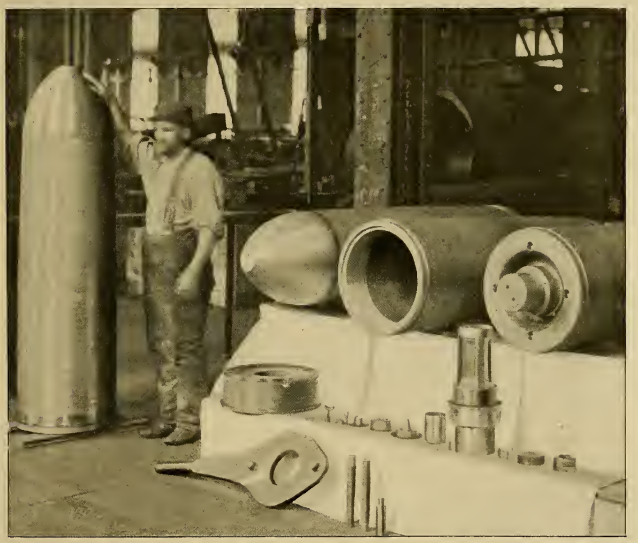
In no respect, perhaps, has greater improvement in gunnery been made in the last dozen years than in the practically universal adoption of smokeless powder. At present the pure nitrocellulose powder is generally held to be the best. Though smokelessness is usually put forward as the great advantage of the modern powder, yet the absence of solid residue in the products of combustion would appear to be the real gain in this regard. In the old powders about 40 per cent. of solid residue was projected from the gun as uselessly as though its weight were in sand, while in the modern powder all or nearly all the charge turns into gas and helps to propel the projectile. On the other hand, the gas of the modern powder, particularly where much nitroglycerine is used in making it up, as is the case in cordite, for example, is of very high temperature and scores and gutters the gun very badly. This is much less so with the nitro-cellulose variety, and with the latter, where moderate pressures are used,—say, of 34,000 or 35,000 pounds,—the scoring of the gun is not a very serious matter.

The scoring of steel by hot powder gas is an extraordinary phenomenon. If there be ever so little a channel through which the gas can escape, the steel is washed out and disappears in a most wonderful way. As, however, the propelling power of powder depends

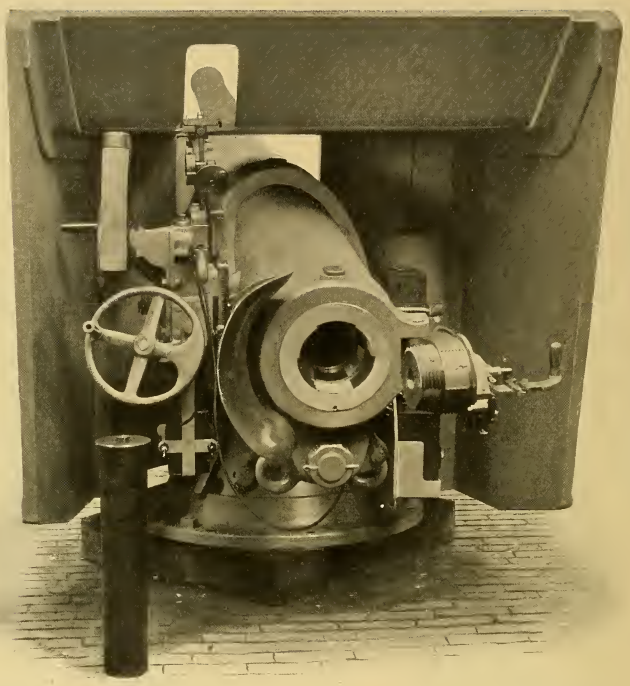
upon the amount of gas given off and upon the temperature to which it is heated, it is desirable, of course, to use as high a temperature as possible. In other words, if the scoring and guttering action of the gas could be controlled, the hotter the latter is the greater the velocity attained would be. As a matter of fact, however, when high pressures,—say, 40,000 or 50,000 pounds,—are reached, the destructive power of the gas becomes very great. When the new powders first came in, it was thought that a charge of one-fourth or one-third the weight of the projectile would be ample to give all the velocity that would be needed; but, owing to the desire to attain very high velocities (3000 feet and upwards), the weights of charges have been creeping up of late until now, in some guns, they approach one-half the weight of the projectile, which is the figure at which they stood roughly in the days of brown or cocoa powder.

It need hardly be pointed out here how important a matter this is as controlling the sizes of magazines of ships. Indeed, in some classes of artillery, as, for instance, in field artillery, where weight is of vital importance, there are many who believe that some form of nitro-glycerine powder may still be used, as it is with shoulder guns.

A word may now be said in regard to the improvements in the quality of steel in guns, and whatever is said about this may apply, it is obvious, to shafting. Ten or twelve years since or thereabouts the tube of a large gun or a large piece of shafting which showed 40,000 pounds elastic strength was considered something rather out of the common; nowadays it is not at all unusual to be able to secure 60,000 pounds elastic strength in the same forging. This could be attained with about 16 per cent. elongation. Indeed, up to guns of about 5-inch calibre, the tube and jacket of



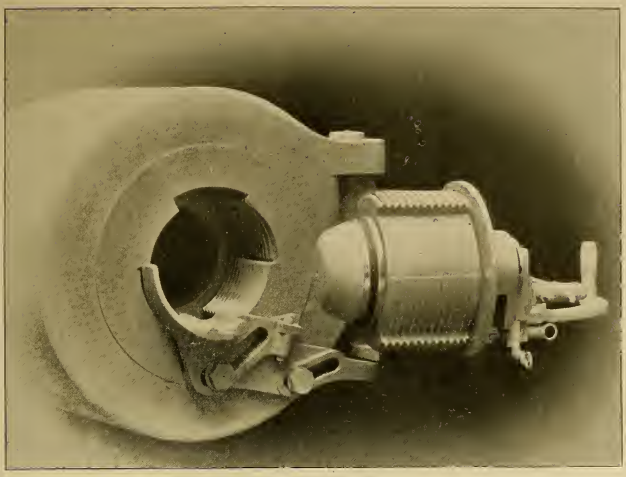
HIGH EXPLOSIVE SHELLS FOR THE GATHMANN 18-INCH GUN. THESE SHELLS CARRY 500 LBS. OF WET GUN COTTON, AND ARE PROJECTED WITH A MUZZLE VELOCITY OF 2200 FEET PER SECOND



ONE OF THE 4.7-INCH GUNS MADE BY SIR WM. G. ARMSTRONG, WHITWORTH & CO., LTD.

which constitute pretty reasonably sized forgings, qualities as high as 70,000 lbs. elastic strength, with 16 per cent. elongation, and about 130,000 lbs. ultimate strength, have been reached, and there is no reason to anticipate that this material is any less safe to use than the softer material. Indeed, all the evidence goes the other way. It would not, perhaps, be desirable to reduce a gun's thickness of wall very materially in case this stronger material were used, but rather to consider the gained strength as so much surety against disastrous accident. Indeed, it would be impossible to materially reduce the weight of guns without increasing that of their carriages, as with a lighter gun the recoil would become much more violent and harder to control. It would be very easy, if desired by ship constructors, to give the gun a larger base upon which to stand and to increase the length of recoil in many instances. As a striking example of this, it may be mentioned that modern quick-fire field artillery use a 3-inch gun 90 inches long, employing a recoil of 40 or 50 inches,—that is, the gun recoils half of its own length. Of course, it might be entirely undesirable to let a ship gun recoil through anything like such a distance as this, but there is nothing impossible about it if desired.

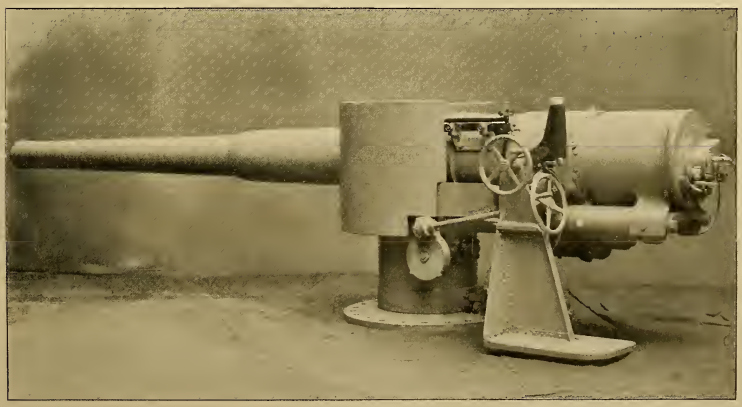
Probably one of the most striking changes made in gunnery in the last few years has been in the field artillery. By means of the long recoil stated, and by the adoption of the so-called spade at the end of the trail, which spade en-



THE BREECH MECHANISM OF THE GUN BELOW

ters the ground, these guns have become capable of a very rapid rate of fire, and have been discharged ten and even twenty times within a minute. The men handling them sit on seats fast to the trail, and anyone who has seen the field guns of a few years since, when in action, will realise what a revolution this means.

It used to be accepted as a sort of axiom in ship design that the armour should be so distributed and the vulnerable parts of a ship so protected that no one shot could destroy her. This has



A SIX-INCH QUICK-FIRING GUN ON CENTRE PIVOT MOUNTING. MADE BY MESSRS. VICKERS, SONS & MAXIM, LTD., SHEFFIELD

EFFECTS OF BURSTING OF A 6-INCH ARMOUR-PIERCING SHELL

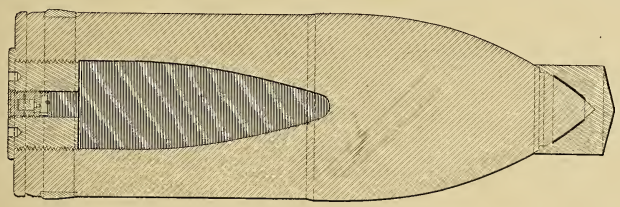
led, in view of the heavy turret guns carried by ships, to the heavy side armour and heavy armour on the turret and barbette. I think a study of naval history will bear me out in the statement that the resistance of ships has been overcome nearly always by silencing the battery and not by destroying the ship. If this be so, a ship should carry large-bored guns of a respectable penetrating and mine power, and their magazines and ammunition supply arrangements should be such that they could be served at maximum rate. Roughly, if the systems of the guns are the same,—that is, if the guns are of the same dimensions, when stated in calibres,—then for every 12-inch gun we may have twenty-seven 4-inch guns, and as the rate of fire of each 4-inch gun is quite five times that of the 12-inch, it becomes apparent how much total metal fired and bursting charge is sacrificed for the heavy turret gun. Suppose a ship, instead of having, say, four 12-inch guns and four 8-inch and sixteen 6-inch guns, should carry about one hundred and seventy 4-inch guns or eighty 4-inch on her broadside, or a total of fifty-six 6-inch. Which would be the better ship? Of course, this parallel may be reasonably com-

bated; but to me it means a great deal. If it be true that ships are overcome by their batteries being silenced,—that is, by their men being driven from the guns,—then the number of shots fired becomes a question of great importance.

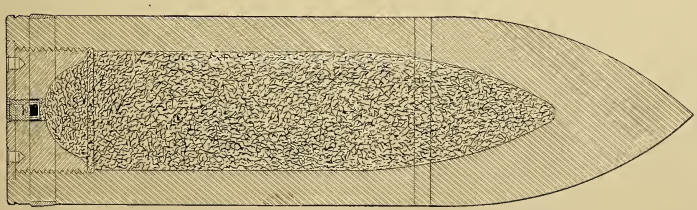
At the present time it may be said that the principal guns of battleships are in turrets, usually in pairs, and are of 12-inch calibre. The thickness of the turret armour is 12 inches usually, or less. The so-called secondary batteries of battleships are composed of 6-inch guns, which are in broadside, and are often isolated by transverse armour and armour to their rears, which makes it unlikely that more than one of them could be silenced by the bursting of a single shell. These 6-inch guns are, for the most part, behind 5-inch and 6-inch armour.

There appears to be no disposition to increase the calibre of the 12-inch turret guns forming the main battery of battleships, though there is considerable movement looking toward making these guns longer and heavier, and, consequently, imparting to their projectiles higher velocities than those now ruling. As respects the 6-inch guns forming the secondary batteries, naval opinion is entirely at variance. In the United States there are many who would substitute 8-inch guns for the 6-inch guns, and others who would substitute 7-inch guns, while in Great Britain the bulk of opinion appears to be in favour of a 7.5-inch gun, whose projectile weighs 200 pounds. To this 200-pound projectile would be imparted a velocity of 3000 or more feet, so that the British 7.5-inch gun is a very large and very powerful weapon. The 7-inch gun proposed in the United States and developed by the United States Navy Department, requires a 160-pound projectile, and to this is imparted a velocity of 3000 or more feet. There is some disposition on the Continent of Europe to use lighter guns in turrets than those of 12-inch calibre, which will weigh from 45 to 50 tons; but in Great Britain and in the United States the 12-inch gun seems to be pretty strongly held to.

The secondary battery guns, however, as stated, are quite unsettled. Besides the 12-inch and 6-inch guns, protected, respectively, by 12-inch and



A 10-INCH CAPPED ARMOUR-PIERCING SHELL. WEIGHT, 500 LBS



A 13-INCH FORGED STEEL COMMON SHELL. WEIGHT, 1100 LBS.

6-inch armour, battleships carry a large number of 3-inch 15-pounder guns, having a high velocity and having very little protection. The large armoured cruisers, which, in their elements of offence and defence, now approach battleships very closely, carry somewhat smaller guns than the latter, and their armour is accordingly reduced. When we come to the smaller vessels of all classes, the protection afforded the batteries is usually very little besides the gun shields, and the side and other armour, of course, is also materially reduced.

There are many reasons why the battleship, armed with 12-inch guns in her turrets and 8-inch guns on her broadsides, which is the favourite battery with those who would push the weight of battery very far, would have great advantages over a battleship carrying only 6-inch guns in her secondary batteries; but, if the muzzle velocities of the 8-inch guns be equal to those of the 6-inch guns, and the total weights of battery are about the same, the number of 8-inch guns would be one-half that of the 6-inch and the rate of fire of the 8-inch, as compared with the 6-inch, would be very materially reduced, —it is, perhaps, not too much to say that it would be reduced by one-half. The 6-inch gun can be man-handled,—that is to say, the shot can be handled by one man and all operations performed with ease, without the use of mechanical apparatus. There are many devices for simplifying the handling of projectiles and getting them into the gun; but it must always remain that the weight of the 8-inch shot,—now 250 pounds,—will continue to be a serious impediment in the way of handling the gun rapidly.

Very little has been said about the numerous small-calibre guns, such as 6 and 3 and 1-pounders. These are now usually either fully automatic or semi-automatic in character, and occupy an important field in certain classes of naval warfare, such as the repulse of torpedo-boats, the protection of mine fields, and in landing operations. As regards a naval landing gun, it has been a rule to regard these in much the same way that the field gun on shore is regarded,—that is, it is a question in which mobility is of great importance. Naval landing guns, however, must be materially lighter than the field gun of the army, which weighs, on its carriage and without any ammunition, about 2000 pounds. This is obviously too heavy to be drawn over rough roads by men, and the naval landing gun, itself weighing some 500 or 600 pounds, usually weighs, with its carriage complete, about 1200 or 1500 pounds, and is of approximately 3-inch bore. The 6 and 3 and 1-pounders are usually conveniently disposed on the rail of a ship and in her tops, and are suited only to the attack of unprotected parts. The 1-pounders and 3-pounders are also sometimes used as landing guns.

To summarise results, it may be said that, in the past twelve years, by the use of better mixtures, by improved heat treatment, and by very marked improvement in face hardening, the power of armour of a fixed thickness to resist penetration has been increased about 40 per cent., while its power to resist cracking has been increased in even greater degree. This has been taken advantage of in large measure in a reduction of the thickness of armour plate on a ship's side. The total weight of armour carried is not less than formerly, and, indeed, it is perhaps greater than it was; but it is more spread out, and, while the protection on the vital parts is as good and perhaps better than it was, there is now some weight in armour left to cover parts that formerly were without protection.

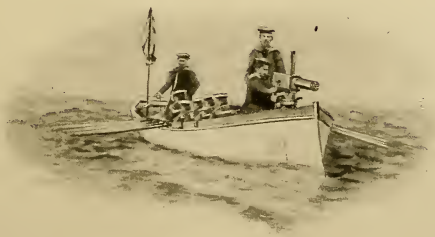
Gun steel also,—and in speaking of gun steel, as previously mentioned, we may include the steel for shafting as well,—has been materially improved in the period under review. The shafting steel now going into ships is very much stronger than that which was used ten years ago. It is, indeed, perhaps quite 70 or 80 per cent. stronger than the earlier material. The advance in gun steel has not been so marked, because ten years ago the purchasers of gun steel wanted an elastic strength of about 40,000 pounds, whereas only 28,000 or

30,000 pounds were asked for in shafting. Now they both run to 50,000 pounds, or even more.

These very desirable and very material advances in quality have been made possible by the adoption of more satisfactory mixtures in the melting furnaces, and by more skillful heat treatment. They have not, however, been accomplished without much experimentation and the expenditure of a great deal of thought and money. The noted advance in the strength of gun steel has not been followed by a reduction in the thickness of gun's walls. Indeed, the gun's thickness is rather greater perhaps than it was, and the increased strength serves only as an additional guarantee against disaster.

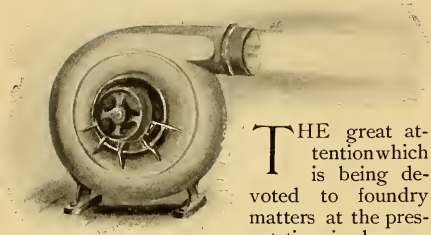
When we come to what may be called the tactical aspects of guns and armour, we find also material changes. The quality of the gun steel and of the armour, as is stated above, has advanced by perhaps 40 per cent., and full advantage has been taken of this in design. The modifications in design which have come about have been numerous. The armour is more distributed. It has come to be recognised that unprotected guns have no chance, and that 6-inch and 12-inch guns should be protected, respectively, by 6-inch and 12-inch armour.

Whether it is better to use a 7-inch or 7.5-inch gun on the same weight as the 50-calibre 6-inch gun,—that is, about 18,000 pounds,—in the secondary battery of battleships, is one of the pressing questions of the day. If the 7-inch or 7.5-inch gun has its weight increased proportionately, it will, of course, be better than the 6-inch gun, except that its rate of fire will be less from the weight of its shot; but, if we take the larger calibered gun and accept a somewhat lower velocity, while using the heavier and larger shot and the same total weight in the gun and carriage, it may well be argued that the larger gun is the better. On the other hand, high velocity gives always an independence of the range at greater distances, and gives always greater penetration. The designer of naval ships is, therefore, on the horns of a dilemma with regard to the battery of the ship, as indeed he must be with regard to pretty much all of her elements, and he must be guided by judgment and by a careful balancing of conditions, so that, upon the whole, and in the circumstances most likely to occur, the ship he produces will be able to give a good account of herself.



THE EQUIPMENT OF THE FOUNDRY

By Joseph Horner



THE great attention which is being devoted to foundry matters at the present time is phenomenal, and unparalleled in the history of this department of manufacture. It is fully as remarkable as the intense interest which is being centred in machine shop equipments. Old-time moulders cannot realise it. If you attempt to explain to them the later and most highly specialised foundry systems, they smile half incredulously, and shake their heads, apparently thinking that you are drawing the long bow.

The wonderful developments of moulding machines alone are quite as remarkable as those of turret lathes, and milling machines. The conveying and hoisting systems of an up-to-date foundry are just as elaborate as those of the turnery and machine shop. As much science and skill is required in the melting of iron as in the working of steels, and foundry appliances are quite as valuable and important as those of any other department. A newly-built foundry, of good design, is inferior in no respect to any other factory building in an engineers' works, either in respect to stability, height, warmth, lighting, or the adaptability and excellence of all its arrangements.

In most districts the old and the new are now brought into close proximity. A highly elaborated foundry will be found within a radius of a mile or two of others which remain to illustrate the ideas and the practice of thirty or forty years ago. It is hardly worth while to note the characteristics of the old foundries. They are familiar to engineers. They make profits still, and doubtless there are many employers and foremen who are not able to realise the growing need for alterations or improvements. But silent changes are taking place which will, by and by, try the old shops severely, and the race at last will be to the firms who are best able to handle their work in the most economical fashion, and to provide the most pleasant surroundings for their men.

In discussing foundry equipment, the writer has in mind the type of shop which vastly predominates over others, —namely the general shop, with departments devoted to some special classes of work. This definition excludes the purely jobbing and repair shops, and those which deal wholly in specialities.

Most foundries are prepared to handle general outside work, even though they manufacture specialities of their own. The difference between general and special work is that of the numbers of castings required from a certain pattern at one time, which may be one, a dozen, a hundred, or a thousand. But even when a firm's work is not specialised to any great extent, there is almost always a certain section of it which lends itself to special and economical methods of manufacture. There are the small parts and fittings which are required in large numbers for use on different sets of work, and most of which can be produced as stock orders, in much larger sets than the bigger details. These small portions, when made for stock, are charged out from the stores to orders, the large parts of which are made specially only for those

THE FOUNDRY OF MESSRS. MATHER & PLATT, LTD., MANCHESTER

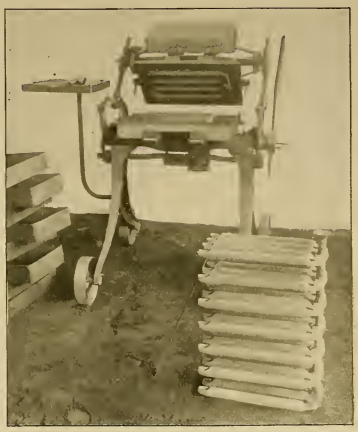
A CORNER OF THE FOUNDRY OF MESSRS. JOHN LANG & SONS, JOHNSTONE, NEAR GLASGOW

orders. In the greater number of foundries, therefore, which would not be classed as specialised, two main classes of work are done, —the general and the special, and though these are frequently not separated as they might be, with resulting economies, they ought to be, and they must be, so differentiated in any sensible scheme of reconstruction.

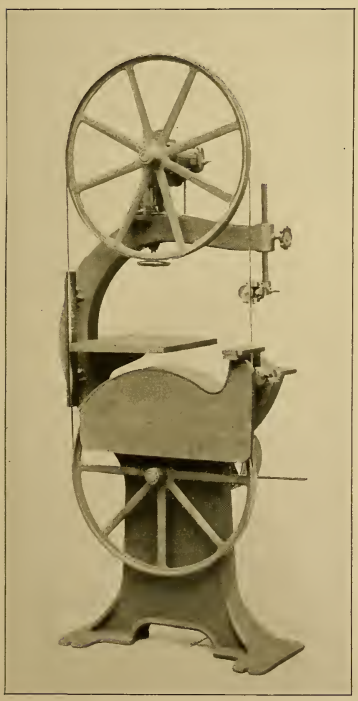
The first thing, therefore, to do is to effect a judicious separation between the classes of work done in a foundry. Formerly the economy of this was not fully realised. Men were changed about on the various kinds of work, and many of the older hands were fully competent to tackle anything, whether loam or green sand, light or heavy castings, make their own cores, and, if required, select and melt their metal. But economy is secured best by separating the several classes of work, and locating each in a different shop, among different groups of men. These are not necessarily, or usually, situated in different buildings, some special cases excepted, but are arranged in parallel bays, separated only by columns, thus permitting free communication, and the supervision of one foreman. Unless,

too, there are regular differences in the grades of metal used, one set of cupolas serves all of the shops. But if the differences in metal are maintained constantly, as soft and grey, tough and mottled, or chilled, or cylinder metal, or very poor metal for fire bars, it is best to have more than one set of cupolas, the dimensions of which will be determined by the daily tonnage of the departments which they have to supply.

Each department of the foundry again requires its own special equipment, that for loam being quite distinct from that for green sand, the light from the heavy,



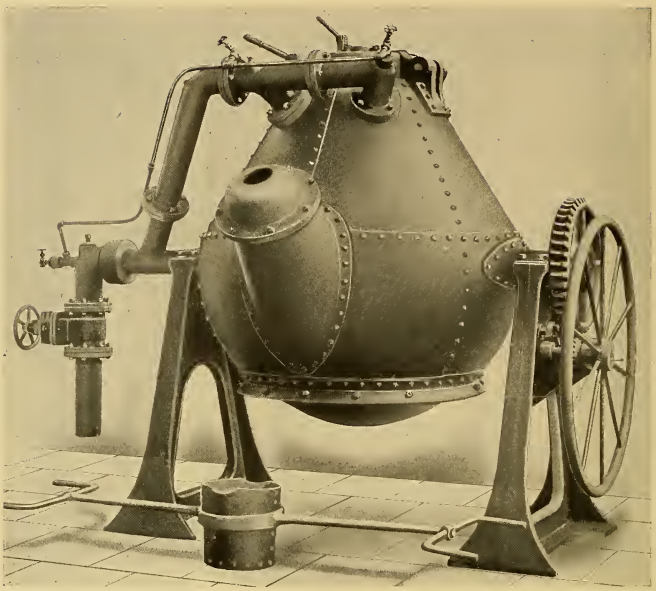
MULTIPLE MOULDED SASH WEIGHTS.—28 CASTINGS IN ALL, POURED THROUGH A SINGLE GATE. MADE ON A TURRET MACHINE BUILT BY THE ADAMS CO., DUBUQUE, IA., U. S. A.



A BAND SAW FOR CUTTING OFF SPRUES FROM BRASS CASTINGS. MADE BY THE BRASS FOUNDERS' SUPPLY CO., NEWARK, N. J., U. S. A. THIS SAW LEAVES NO STUB END TO BE GROUND OFF

the core-making from the moulding, the hand-moulding from the machine-moulding, and the brass from the iron.

The loam department is one of great importance in some works, and unrepresented in others. The question of moulding in loam in preference to green or dried sand is partly one of dimensions, partly that of the number of castings required from one pattern, and equally that of the soundness of the castings. Many very large castings are moulded in green sand, either with or without full patterns, and the question of making these in loam is not considered; but there are certain jobs which no one would risk making thus. Familiar illustrations of this are large marine cylinders, large propellers, large casings for centrifugal pumps boiling pans, condenser castings, big pump barrels, and other work which is subject to great pressure either of steam or water. Loam work can be relied on to produce sound and solid castings, of massive dimensions in tough mottled irons. The risks of blows, sponginess, scabs, and internal strains are less than in green sand work. The equipment of the loam de-



THE SCHWARTZ MELTING FURNACE, MADE BY THE HAWLEY DOWN-DRAFT FURNACE CO., CHICAGO, RESEMBLES IN APPEARANCE A BESSEMER CONVERTER, SWINGS ON TRUNNIONS, AND MELTS ITS CHARGE BY MEANS OF A BLAST OF OIL AND AIR DELIVERED THROUGH TWO TUYERES

partment is altogether distinct from that of the sand moulding shops. No moulding boxes are used, but prodded plates, and rings in large numbers, and dimensions. These are cast in the first place for special jobs, and then are usually stacked for future service. Centres, and bars for sweeping up, quantities of bricks, wood blocking and iron trestles are wanted here. Pits are required in the floor and drying stoves opening into the foundry walls, cranes, grinding and mixing mills for the sand and horse manure used, slings, beams, cross bars, etc.

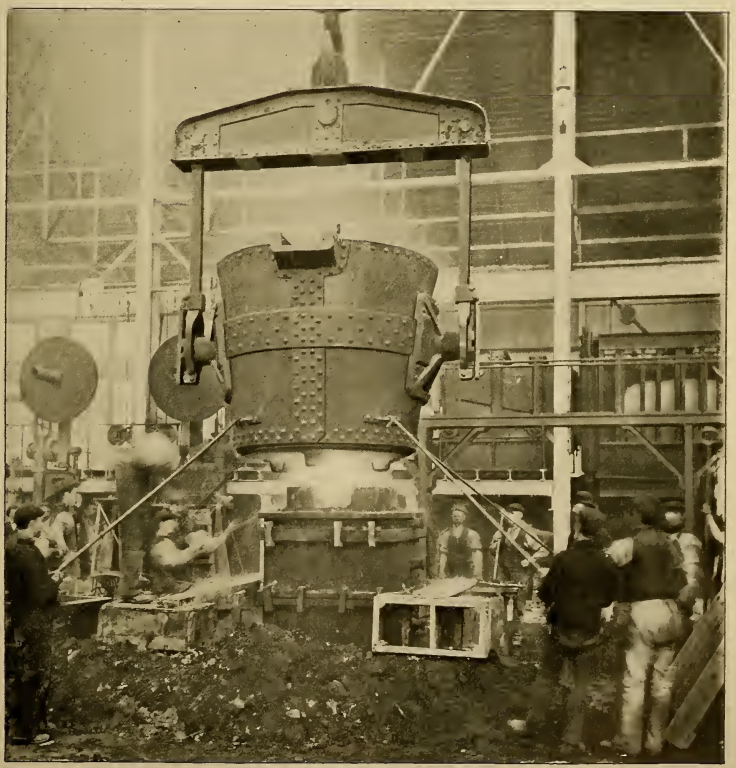
This department has been affected less than any other by improved equipments. Excepting that it shares, in common with others, in the better lighting and ventilation of shops, and improved hoisting facilities, it remains practically as it was thirty years ago. It requires all hand work of a particular training. It flourishes most in marine engineering and general engineers' shops. Plenty of room and ample margin of power for hoisting are most essential here. The appliances employed must grow with the growth of a foundry; they are not laid down at once. Plates and rings are made as they are required, and then stocked. It would be impossible to gauge beforehand the extent of the loam equipment for a new foundry, except in the case of a firm moving from old into new shops, and continuing to carry on the same class of work. It is necessary to make a moderate beginning, and subsequently add whatever is wanted.

The green sand department is usually divisible into light and heavy. These terms are relative, since what is light in one foundry may nearly correspond

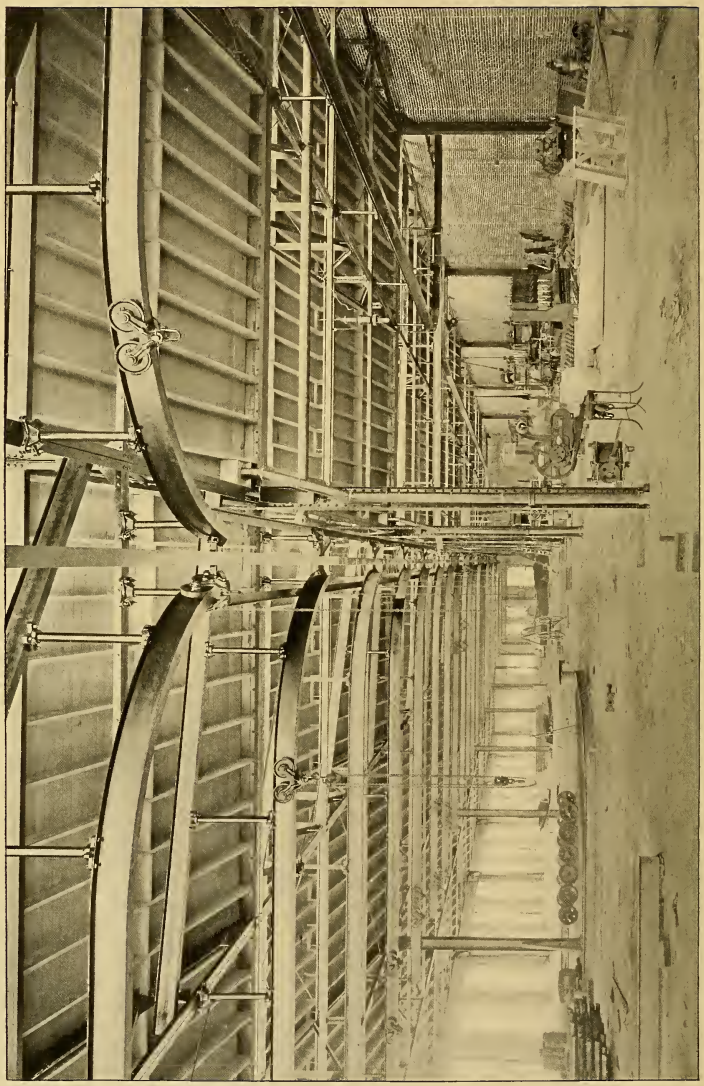
with the heavy in another foundry doing a different class of work. This division affects the magnitude of the tackle used. Heavy foundries are served by overhead travelling cranes; light ones by small cranes, if any. Overhead tracks, or wheelbarrows, and trolleys often suffice for their requirements.

The moulding boxes are the most bulky item in the green sand shops, growing until, like stored patterns, they become a nuisance, demanding more storage room than is available in some works. A wise plan is to scrap all boxes except those kept for standard service. Those made for special jobs often lie about for several years without being brought in again. Small boxes can generally be stored inside a foundry; big ones must almost always go out in the yard adjacent.

Moulding boxes are not only bulky, but they constitute a more important part of the plant of a foundry than they are often thought to be, if we may judge by the specimens frequently seen. Appreciation of good boxes has been growing of late years, which is due in a large degree to the increased adoption of plate and machine moulding systems. These soon find out the inaccuracies in boxes. One improvement relates to the pin fittings; another to the use of snap flasks. For the immense majority of



IN THE STEEL FOUNDRY OF THE BRITISH WESTINGHOUSE ELECTRIC & MFG. CO., LTD., MANCHESTER

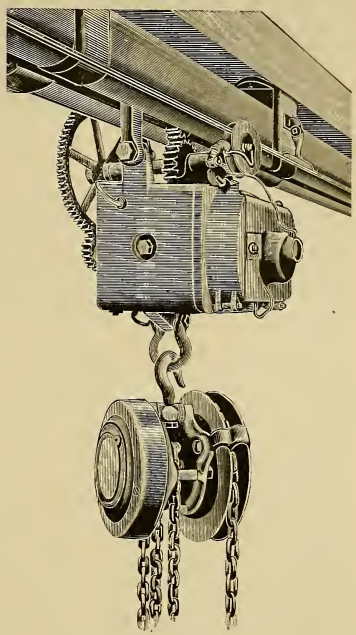


AN OVERHEAD I-BEAM TROLLEY SYSTEM AS INSTALLED BY THE CURTIS & CO. MFG. CO., ST. LOUIS, MO., U. S. A.

boxes the old style pins and lugs retain their place. The important difference now is that boxes of the same size in a well-equipped works have their pins and holes all made interchangeable, instead of the box parts being fitted separately, and being interchangeable only by chance slackness of fitting. Such boxes produce bad moulds with lapping joints. Turned pins, and holes drilled to templet insure interchangeability. Then again the use of moulding machines and plates makes uniformity essential, and this has helped to bring the bad boxes into disrepute. Some machines require boxes with special pin fittings; others do not.

Snap flasks might form a much larger portion of the equipment of light foundries in Great Britain than they do now. The moulds made in them are cast after removal from the flasks, the latter being opened, and the mould taken away on a bottom board. The moulds are laid close together side by side to afford each other mutual support to resist the pressure due to pouring. A weight with openings for pouring is laid on top. The same system of removing the moulds from the box frames in which they have been rammed is adopted in several moulding machines, and the practice is a growing one. Bands or frames are used in many instances to bond the outside of the sand. This system is suitable for shallow, light moulds, but not for deep ones. The advantages are, the saving in expense of boxes, which runs into large numbers in foundries doing light work, whether with plates or moulding machines; and the saving of space which results from being able to lay out finished moulds without the additional bulk of the box surroundings. This makes a considerable difference in floor space.

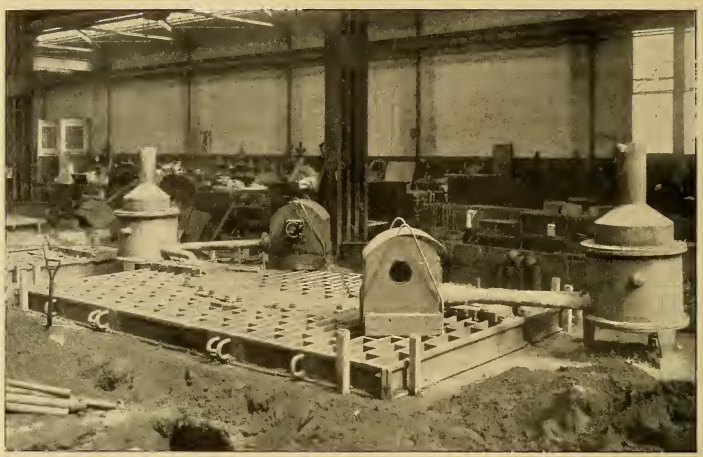
Both dried and green sand work is done in these shops rather than in the loam department, because the same moulding boxes are used for dried as for green sand moulds, and the methods of moulding are alike. Where very heavy work is done, a pit is often required, as in the loam shop, to facilitate putting the work together, and pouring it. Work may be dried, or only skin dried, in a pit or in drying stoves. The drying of moulds in the pits, or on the floor is usually done with portable "devils;" but better systems are in existence in which hot gases



AN ELECTRIC OVERHEAD TROLLEY TRACK CARRIER FOR FOUNDRY AND GENERAL SHOP SERVICE. MADE BY THE COBURN TROLLEY TRACK MFG. CO., HOLYOKE, MASS., U. S. A.

are drawn down into the closed moulds, and with a great diminution of the objectionable fumes of sulphur that arise from open coke fires. Grinding mills, disintegrators, sand mixers, and a large number of storage bins for sands, are also required in these departments.

The core-making department is either a single one, serving all the hands in a small shop, or, if the foundry be large, each shop will have its own set of core makers. Here the equipment includes



PORTABLE HOT AIR FURNACES FOR DRYING MOULDS IN THE FOUNDRY OF THE GENERAL ELECTRIC CO., SCHENECTADY, NEW YORK. EACH OF THESE CONSISTS OF A PORTABLE ELECTRIC FAN OR BLOWER SET, PLACED NEAR THE MOULD TO BE DRIED. THE BLAST OF AIR FROM THIS IS CARRIED TO A COKE STOVE HAVING AN ANNULAR RING AROUND THE FIRE. IN THIS THE AIR IS HEATED AND IS THEN FORCED DOWN INTO THE MOULD. THE DRYING IS DONE QUICKLY AND UNIFORMLY

drying stoves, stove trolleys, and a large amount of tackle, grinding mills, core barrels, trestles, strickles, core plates, standard core boxes and benches. A moulder is often also an expert core maker, but core making is mostly done by lads and men who have not had a moulder's training. The stoves are generally heated with coke, but producer gas may be utilised when a firm is equipped with a producer plant.

The brass foundry equipment resembles that of the light iron foundry, so far as the moulding appliances are concerned. The principal difference lies in the furnace design. Brass moulds are made both in green and dried sand, are swept up in loam, require dried cores, and are made by hand, or machine methods. This department is kept distinct from the iron foundry, and generally in a separate building.

The machine departments are those in which specialised articles are made in quantities by moulding machines acuated by hand or power. The work of plate moulding is a stage in this direction, since the same plates can be moulded by hand, or put on a machine. By "machine moulding," plated work is always understood, though wheel moulding is done in large quantities by machines of another kind. The possibilities of machine moulding greatly exceed those which were deemed practicable a few years ago. Only comparatively few classes of work now lie beyond the range of the machines, such as loam moulding, swept up, and segmental moulds, those of very large dimensions, bedded-in work, work involving stopping off, and alterations from the patterns. Even cores of some kinds now afford a legitimate field for the operation of machines.

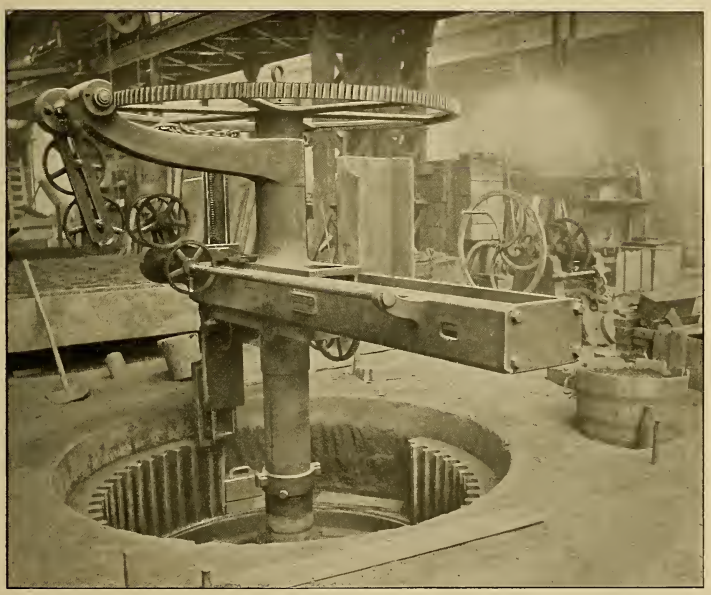
Having thus noted the broad differences between the various departments that constitute the foundry, special attention may be given to some of those recent developments which loom so large in modern equipments. Much will have to go by unnoticed in the

limits of this article, but the more salient matters can be treated summarily.

Cupolas and metal are burning questions, the discussion of which seems limitless. The melting ratio has been a big bone of contention among foundry managers and their employers, due to the want of a fair appreciation of the differences which exist in different foundries doing diverse classes and qualities of work. The melting ratio depends much less on the cupola used than on its management, less on its management than on the length and weight of the day is run more economically than one pouring very late in the day.

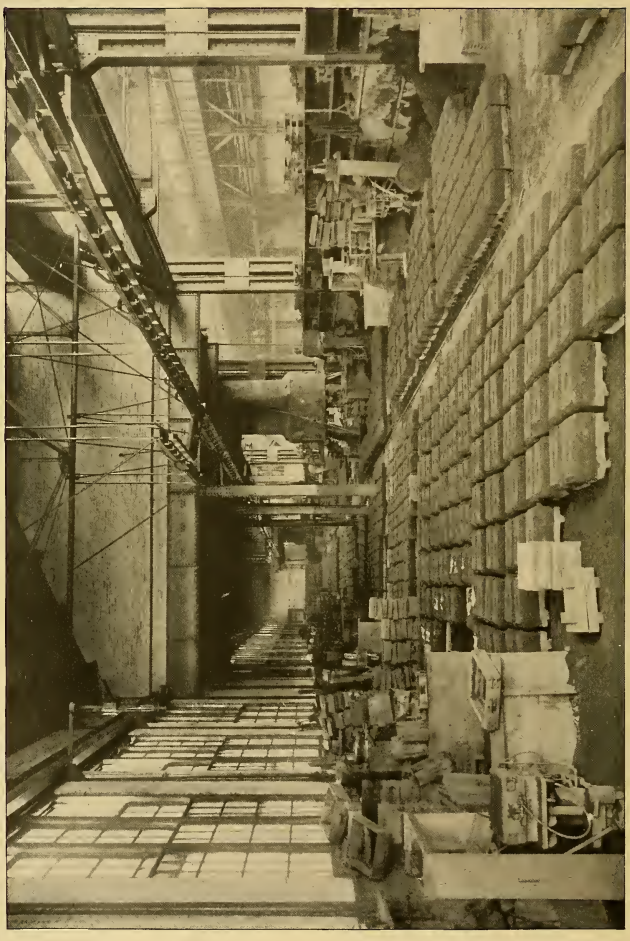
A cupola melting large quantities regularly, is more economical than one doing a light class of work. Metal that is melted dead, *i. e.*, thoroughly fluid, must take more fuel than the same insufficiently melted, so that the proportion of wasters is larger with the latter than with the former. These are the differences that must have first attention.

Though there are several good cupolas which leave little room to choose



A GEAR WHEEL-MOULDING MACHINE IN THE FOUNDRY OF MESSRS. SULZER BROS., WINTERTHUR, SWITZERLAND. THIS MACHINE WILL MOULD GEARS UP TO 18 FEET IN DIAMETER

the blow, on the materials put in, and on the quality of the metal that comes out. The bed charge, which bears so large a proportion to the total weight of coke used in a short blow of two or three hours, is nearly neglible in a blow of say, eight hours, and thus a foundry pouring nearly continuously through among them, there are none that will yield satisfactory results unless they are in charge of good melters. The work of melting metal, though done by so-called unskilled men, or men without a trade, is as much an art as moulding itself, or steel or brass melting. An incompetent man will not tap out the



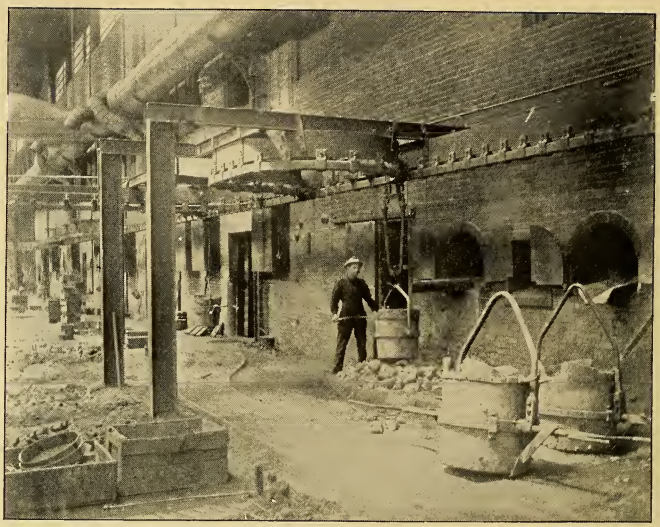
THE MOULDING MACHINE SECTION OF THE FOUNDRY OF THE GENERAL ELECTRIC COMPANY AT SCHENECTADY, NEW YORK. THE MACHINES THERE USED WERE MADE BY THE TABOR MFG. CO., OF PHILADELPHIA

same class of metal that a good hand will, but he will run something into the ladle that produces unsatisfactory castings. The failure to secure perfect melting is often due to ignorance, but more often it is the result of an endeavour to get a high melting ratio, thus risking wasters in order to save coke. Or again, it is due to the employment of inferior coke, low in heat units, or overcharged with sulphur. It is well to mention these things, because there is a too common impression that some cupolas possess occult, economical virtues which are bound to effect great savings in the coke bill. As far as the cupola* design is concerned, the essential points are good height, complete and even distribution, and proper regulation of the blast in the melting zone.

A common cupola of good height, with single or double rows of tuyeres, and blast regulated to suit the nature of the melting being done, will produce good results. Ireland's cupolas gave the best results a generation ago because they were tall, and height utilises the heat to the best advantage. Belts of tuyeres, and double rows of tuyeres are better than two or three tuyeres only, because they distribute the blast more equally. Double rows, capable of regulation, permit of melting light or heavy charges at will, and of more rapid melting than a single row, while a receiver is a useful addition to big casts, as tending to a better mixing of the metal. Increasing blast pressure results in more rapid melting; but pressure must also

RAMMING MOULDS BY COMPRESSED AIR POWER WITH RAMMERS MADE BY THE PHILADELPHIA PNEUMATIC TOOL CO., PHILADELPHIA

*It may be found worth while here to refer to two articles on foundry cupolas in earlier issues of this magazine, one entitled "Modern Cupola Practice," by Dr. R. Moldenke, May, 1901, and the other, "The Foundry Cupola," by Robert Buchanan, May, 1902.—THE EDITOR.



OVERHEAD TROLLEY EQUIPMENT IN A FOUNDRY, INSTALLED BY THE COBURN TROLLEY TRACK MFG. CO., HOLYOKE, MASS., U. S A.

be varied to suit the coke, hard coke requiring more than a softer quality.

The equipment of the cupola includes blowers, or fans, a stage, or a room, a hoist, a weighing machine, and trolleys. The selection either of blowers or of fans is an open subject, excellent results being obtained by the best kinds of each. The present-day ideas of the cupola stage, or room, differ from the older in the respect that more area is allowed. The old stages were barely large enough for a man to move about on, and the metal and coke were brought up just as wanted, in a hand-to-mouth fashion. A stage, or room, is now generally built in new foundries, large enough to contain the whole of the materials for a day's melting.

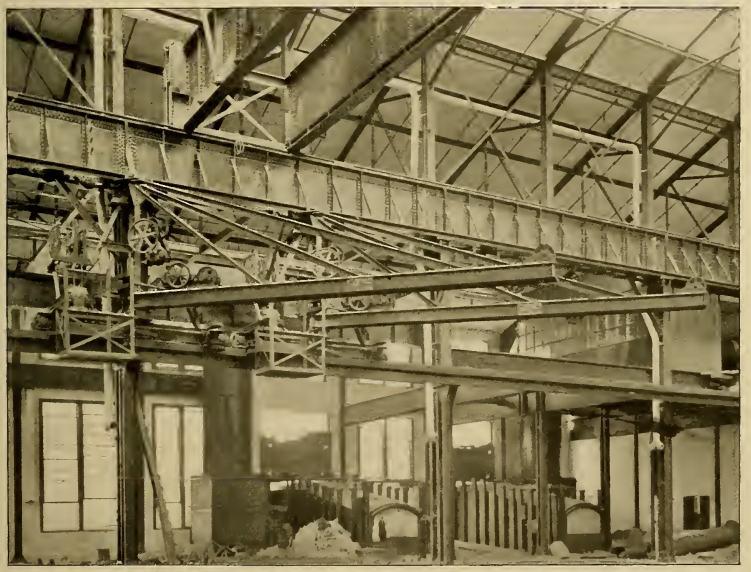
The old cupola stages were frequently uncovered. Now they are completely enclosed, and protected from the weather. The hydraulic or electric hoist have partly displaced the old hand winches, and the trolleys run and dump the weighings of pig, scrap, coke, and limestone in piles. Every bit of material is weighed on the stage, excepting frequently the coke, which is as often loaded in baskets, and the material not used is credited to the next day's stock. In this way time is saved, and the exact melting ratio is known, which is not the case where the coke for general foundry use is not kept distinct from that for the cupolas.

Foundry ladles include three or four broad types. There is the crane ladle, with worm gear for tipping, slung and carried by the travellers, or swinging cranes. These are required in capacities suited to the weight of the work done. But excessive sizes are not used in the average shops, six to ten tons being the maximum. Moulds requiring more metal than a single big ladle will hold, are served by two or more ladles. The shank ladles, carried by two or three men, are handy for taking metal in among the boxes away from tracks, but they are not used quite so much as formerly. There are the track ladles running either on rails, or on cast iron floor plates sunk in the floor, and used either

for pouring moulds down the line of tracks, or for supplying men using the small hand ladles about the shops. The trolley ladles are employed more than ever in diversified forms, because tracks and plates are more common than formerly.

When improvements in foundry equipment are held in mind, many seem to think that these lie almost wholly in the utilisation of moulding machines. This is far from being the case. The machines effect very important economies in some shops, but they constitute only one aspect of those developments which have been taking place of late. The work of many firms is of such a character that they can derive only limited advantages from moulding machines. Questions of hoisting, hauling, melting, and systematising may with these firms often prove greater sources of economy than the introduction of moulding machines. With this proviso, let us see what moulding by machine is doing in those shops where the work done is adapted to the employment of this system.

Moulding machines and systems have grown, and are growing at so unprecedented a rate that it is difficult to enter on the subject at all in the compass of a few paragraphs. Practical patents follow each other rapidly, and the makers of machines are constantly bringing out improved forms of old types. The earlier difficulties that seemed to militate against the work of machine moulding are fast disappearing, such as three-part moulds, moulds of several feet in length,

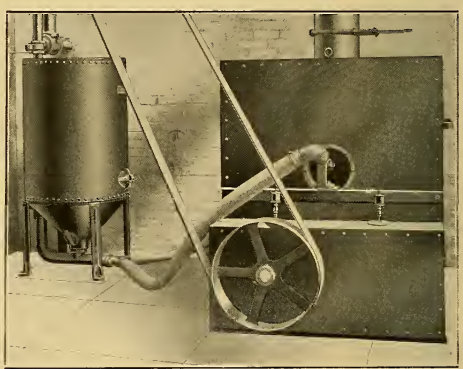


WALKING JIB CRANES IN THE NEW FOUNDRY OF THE WESTINGHOUSE MACHINE CO. AT TRAFFORD CITY, PA. THE CONVENIENCE OF THESE CRANES, OF WHICH A NUMBER ARE ARRANGED ON BOTH SIDES OF THE MAIN BAY OF THE FOUNDRY, IS AT ONCE APPARENT. THEY SERVE ALL THE PURPOSES OF ORDINARY LIGHT OVERHEAD TRAVELLING CRANES. THEY WERE BUILT BY MESSRS. WM. SELLERS & CO., INC., OF PHILADELPHIA, AND ARE DRIVEN BY WESTINGHOUSE ELECTRIC MOTORS

deep moulds, power ramming, everything in short is being invaded. Incidental mention may be made of the pneumatic rammer, which is a mechanism applied to the most important tool of the moulder, economising time in large moulds made on the floor. Even the work of core making is being taken up by moulding machines specially adapted thereto. Germany is unusually active in the manufacture of machinery of various kinds, running American firms very closely, and numbers of foreign-built machines are now in operation in British foundries.

As much specialisation is now going on in moulding machines as in any single class of machine tool. A bare classification of these, with explanatory observations, would fill the whole of this article. So many types are made, in so many different sizes, that there are few foundries that cannot find some machine, or machines, adapted to some sections at least of their work. This system is a highly elastic one, suitable for the moulding of only a dozen, or of ten thousand similar pieces. In some cases ordinary patterns can be used; in others expensive pattern plates have to be prepared. But the expense need be only relative, for when spread over hundreds or thousands of moulds expensive "rigs-up" are most economical. A big item of cost in machine moulding was formerly the stripping plates. But these can be made for a mere trifle by casting white metal inside the edge of the plate round the pattern. Another difficulty has existed in the unsatisfactory results which have followed from power ramming. It should be understood that power ramming is suitable only for those classes of moulds which are neither very deep, nor very irregular in outlines. A good deal can be done by the preparation of pressing boards to conform to the profiles of the patterns, but in spite of the scores of patents that have been taken out for power ramming, the hand rammer is still best retained in a very large amount of machine work.

A broad difference exists between the fixed and the portable systems. All the old machines were fixed; most at present remain so. But the portable machines are growing rapidly in numbers. The difference is that of bringing the materials and boxes to the machines, and that of taking the machines to them. This is of greater significance than may appear at first sight. Moulding machines, as a rule, are so rapid in their action that the work of one alone will fill a large floor area before pouring time. Flasks of sand are heavy, and therefore when machines are fixed, some kind of conveying system is necessary if labour is to be saved. This has taken three forms in shops, one that of parallel rails, along which the boxes are slid away from the machine; that of an annular table moving around its vertical axis; and that of overhead tracks, besides some special conveying systems. In each case, hands are wanted to take charge of the flasks. In a system of portable machines the boxes are handled only once, being simply lifted from the machine and deposited on the floor ready for closing, and the machine is



A SAND BLAST TUMBLING BARREL FOR CLEANING CASTINGS. OPERATED BY COMPRESSED AIR AT FROM 10 TO 30 LBS. PRESSURE. MADE BY THE J. W. PAXSON CO., PHILADELPHIA

AN OVERHEAD TROLLEY EQUIPMENT FOR FOUNDRY SERVICE INSTALLED BY MESSRS. J. W. MOYER & CO., PHILADELPHIA

moved further on as the area around it is covered.

This system, however, is not applicable to the heaviest machines of all, but only to the smaller and medium ones. For fixed machines the conveyor systems are suitable, sand and boxes being brought to and carried away from them.

The question of power or hand operation need not offer great difficulties to a firm that wants to make a selection. Many detached foundries have no power plant, and it is satisfactory to know that there are many excellent machines of considerable size that are operated by hand without an excessive demand on muscle. Even in the smaller types made, greater attention is now given to arranging the levers so that the pressure given to them shall be accomplished with the least expenditure of labour. If large machines are laid down, hydraulic power should be installed in preference to any other. Failing that, steam, and compressed air give good results in some designs.

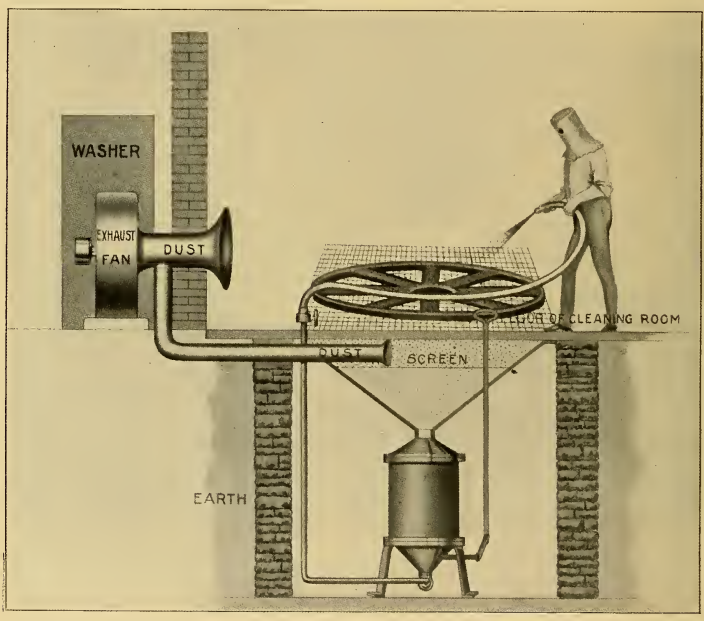
The whole question of machine moulding is fast becoming one on which expert knowledge is necessary to obtain the best results. Comparatively few

foundry proprietors know how much is being done in this line, and how rapidly things are moving. Certainly, machines are sometimes installed quite unsuitable for the work they have to do, on the recommendation of interested agents.

Hoisting, and hauling arrangements must not be selected just because some other foundry has such and such arrangements. They can be considered

trical traveller necessary in such shops, for a hand-operated one answers all requirements.

The place for swing cranes is in localities where a good deal of lifting is regularly going on within a moderate area. The place for overhead tracks is in foundries doing light work, and work also of a uniform character, as, say, plate, or machine moulding, and in



A SAND BLAST OUTFIT FOR CLEANING CASTINGS, MADE BY THE S. OBERMAYER CO., CINCINNATI, OHIO, U. S. A.

only in direct connection with the requirements of any individual shop. On the whole, the most favourable consideration should be given to overhead travellers rather than to cranes and hoists. The traveller leaves the floor clear, and the roof light unblocked, and it covers every inch of the floor area. The fact of its being overhead does not necessitate its operation from above in shops where the service is very intermittent. Neither is an expensive elec-

serving the moulders with ladles of metal from the cupola. A good many things have to be considered and thrashed out before a foundry can be fitted out with the hoisting tackle most suitable to its necessities.

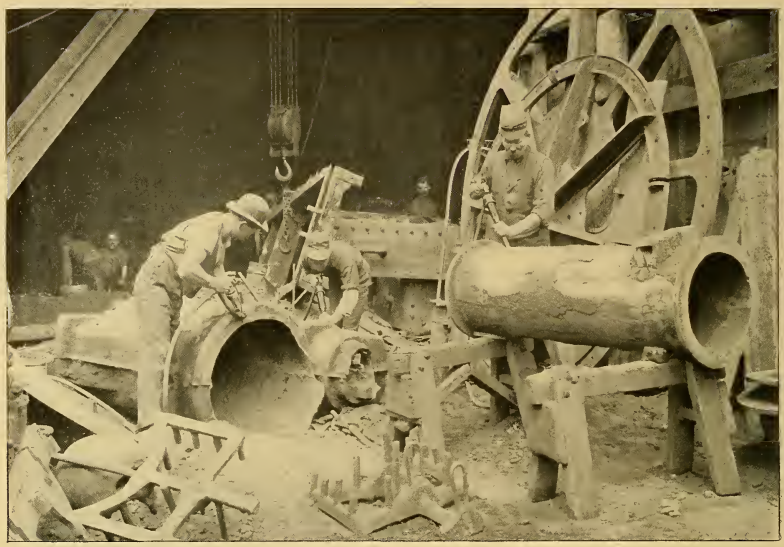
Though the general work of foundries is best performed by an electrical overhead traveller, certain areas, where a crane will often be tied up for considerable periods, should have swinging jib cranes. These areas are those adjacent

EXHAUST TUMBLING BARRELS MADE BY THE STOVER MFG. CO., FREEPORT, ILL., U. S. A.

to the core stoves, occupied by the core makers, and sometimes the foundry pits, and loam moulders, when doing chiefly a light class of work. In laying out the number and class of cranes in a foundry the nature and weight of the various departments of work done have to be carefully considered, and ample and suitable hoisting tackle should be provided to cover the weight not of the castings merely, but of the boxes and their sand as well, which will add from 50 to 100 per cent. to the casting weight. It has been a reproach to nearly all the old foundries that the hoisting appliances have been neglected, the work of unskilled labour has been increased, and much time lost by moulders waiting for cranes that have been held up with other work for half an hour, or an hour at a time, as must often be the case.

With regard to tracks,—now being laid tardily in a few foundries,—these are of the highest value in heavy shops where, with the electrical traveller or travellers, they combine to form the perfect system of haulage and hoisting. But they are not so essential in light foundries, and in some heavy foundries that handle loam work, or very massive green sand moulds they are not desirable. Much of this class of work has to be taken apart and laid about on the floor, so making the keeping of a clear gangway almost impossible. And the plates, rings, and boxes are often so large that they cannot be so readily carried on narrow gauge tracks as by the overhead travelling cranes, and if they could, they would stand out too much to the right and left in a shop crowded with portions of moulds lying about. The area available for foundry work must always be calculated on the basis of the most crowded condition, that is, during the progress of the work, and not when the moulds are snugly closed for pouring.

It is even more essential in the foundry that tracks or plates should be laid



PNEUMATIC CHIPPING HAMMERS FOR SMOOTHING UP CASTINGS, MADE BY THE RAND DRILL COMPANY, NEW YORK

down than in a machine shop, or turnery, having a stone or wood floor, because the sand of the foundry makes haulage of stuff difficult. The sand floor is one reason why the gang of labourers is necessarily large in many foundries, from half a dozen to a dozen men often being required in hauling a heavy box or casting on a trolley. Hence some foundries that do not use rails lay down flat plates of cast iron along the centre of the shop to lessen the tractive effort of pulling boxes, castings, and metal about.

One result which is being brought about by the labour-saving devices in the foundry is the diminution of the proportions between moulders and unskilled labourers. The latter have borne too large a proportion to the moulders in most of the old shops; in others where this has not been the case, labourers' wages have been saved, with the result of throwing their work on the better paid moulders. In a well-equipped shop the labourers are few, but the moulders have to do nothing but their legitimate work of moulding. The work of sand mixing, knocking out the boxes, watering, and levelling the sand is done for them, because cranes, and machines, and trolley tracks relieve the labourers of most of the heavy tasks which they had to perform in the older poorly equipped shops.

Small tools and appliances are too often regarded as unconsidered trifles by those who are responsible for foundry equipments. It is a regular thing in shops for highly paid men to be wandering about calling for "dry brush," "wet brush," "blacking bag," "eighth sieve," and so on, simply because the supply of these is too small. And this leaves the way open for waste of time of a less legitimate character, such as yarning and loafing. The articles mentioned are of less value than men's time, and should be supplied freely.

The fettling department is becoming better equipped than of old. At one time emery wheels and tumbling barrels

were rare, and chipping chisels, and half-worn files discarded by the fitters were used on all castings, heavy as well as light, for cutting off runners, fins, and scabs. At present even heavy castings are not of necessity fettled, or ground by hand; for pneumatic chisels and emery wheels, carried at the end of flexible shafts, electrically driven, bring the tools to the work. The fettling shop may now be as well equipped with tools and appliances as any other portion of a modern foundry.

The presence or absence of power plants often dominates the choice of large sections of the equipment of a foundry. Especially is this the case in those foundries that are detached from general engineering works. Frequently the blower drive and the mill drive settles the question for the rest of the plant. As often as not these are operated by a small steam engine, which supplies little reserve of power for operating anything else. This helps to explain why hand travellers, and hand-operated moulding machines and cupola hoists are commonly used. But in large works there is generally a choice of other agencies, as water for hoists and moulding machines, and steam for cranes. An air compressing plant has to be laid down when the pneumatic system is adopted.

But the flexibility and convenience of electricity are rapidly changing nearly all the old limitations, electric power being equally applicable to cranes, blowers, fans, grinding mills, fettling wheels, hoists, and lighting. Although at present so many firms lay down two or three different plants, as water, air, and electricity, in time the latter universal agency will be the only one retained, and a great simplification will thereby be attained, instead of the mass of connections of different kinds incidental to each power plant.

It is beginning at last to be recognised that a foundry needs warming and ventilating. But in the greater number of foundries the old conditions remain. In the winter morning it is bitterly cold, and the men's feet and fingers suffer in the wet raw sand. "Devils" for drying moulds are suspended later in the day, or, as a concession, they may be lighted early to warm the shop, and straightway the foundry is filled with sulphurous fumes from the coke, which affect the throat and eyes badly,—especially those of the crane men overhead. The same result follows from the opening of the doors of the core ovens. Then the big shop doors are thrown wide open to get rid of the suffocating atmosphere, and the last state is worse than the first. In the afternoon, at casting time, the place becomes insufferably hot, from which atmosphere the men go home through raw frost or snow.

It is only in a few shops now that a proper system of warming and ventilation has been introduced. And yet it is so simple and so perfect in operation when installed. A few very big firms now make a speciality of this work, and the same apparatus is used for both purposes. Even if a foundry is not properly warmed it can easily be ventilated, simply by fans in the walls, electrically driven. This would be a boon at casting time, when fires are lighted, or core stoves open, and on hot summer days. Quite apart from humanitarian motives the comfort of the men is a paying asset, for men can work at their best only when comfortable.

ELECTRIC RAILWAYS IN THE UNITED STATES

THE RESULTS OF FIFTEEN YEARS' DEVELOPMENT

By Lemuel William Serrell, M. E.

IN the early part of 1888 only 86 miles of electric railway were in operation in the United States, using about 172 cars. The census report for June 30, 1902, showed 22,589 miles of electric road, using 67,199 cars, and requiring 1,298,133 H. P. for their operation. The number of passengers carried during the year was nearly 6,000,000,000. The total gross earnings reported were $241,584,697, and the operating expenses were $139,012,004, leaving net earnings of $102,572,693. The total number of employees was 138,183, and the wages paid them amounted to $84,636,275, or an average of about $614 each per annum. The above length of line has now been increased to nearly 26,000 miles.

The original electric cars were usually old horse cars mounted on improved trucks carrying electric motors of about 20 H. P. capacity, having a maximum speed of about 12 miles per hour. Today we have not only city railways, but interurban railways, operating on private rights of way, carrying passengers, express, and freight matter, equipped with cars that will run a mile a minute, and we find some of the electric roads now putting on sleeping cars nearly 60 feet long, each equipped with 600 H. P. in electric motors, and ten compartments, with upper and lower berths that fold up during the day time, and so arranged that the cars can be converted into parlour cars having twenty chairs for the day service.

This wonderful growth in such a short time has created in the minds of the promoter, the banker, the investor, the citizen, and the politician the idea that fortunes are easily made in the construction and operation of electric railways, or such phenomenal results could not have been accomplished. Such results have been a temptation to both the promoter and banker to approve of overcapitalisation, and in many cases the investor has already proved the victim. But worse results still have been produced politically.

The uninterested citizen has been led to believe that the municipal councils have been giving away the use of the highway without adequate compensation, and many corrupt politicians have made street railways pay high for the privileges so granted. The voice of the public likewise has compelled the municipal councils to introduce restrictions into the franchises asked for, which have become more and more unfair to the railway companies, until now franchises are so burdened with conditions that the construction of a road has become exceedingly expensive, and the short life of the franchises are not more than sufficient to allow the companies to get well established before the municipalities demand a readjustment of everything regarding compensation.

This rapid development of electric railways is very different from the development of gas and water companies, for we find that the first gas company was built in America in 1816 in the city of Philadelphia, and the development of gas has been quiet and gradual and extending over many years. Gas and water mains are out of sight in the streets, and consequently have not attracted as much attention from municipalities, and the companies have had a

fairer chance to live and make a reasonable profit without being burdened with too many onerous restrictions.

It is a very serious question that confronts the investor to determine whether or not it is safe to buy street railway securities. There is no doubt that good street railway securities form the basis of a very safe investment, but over-capitalisation has crept in, municipal regulations and conditions have become too severe, the expense of construction has been increased, and in many cases street railway companies have not made proper provision for maintenance of track and equipment. Accidents on street railways are about eight times as frequent as on steam railways, and provision must be made to settle the claims for these out of earnings.

The report of the Milwaukee Railway & Light Company for 1902 shows 3791 claims of all classes for accidents, of which 658 were settled at a cost of $51,-847. This company sets aside 4 per cent. of its gross receipts to establish a reserve fund to pay for accidents, the amount of this reserve fund being about $100,000 per annum.

Labour troubles likewise have crept in until strikes on street railways have become more numerous and dangerous to life and property than has ever been known in steam railway operation, and the settlement of any strike always means a loss to both sides.

It is not the purpose of this article to be pessimistic, but simply to bring forward both the good and bad sides of the situation for calm consideration.

It is to be regretted that outside of the State of Massachusetts inflation and over-capitalisation have been too freely indulged in. As an illustration of this point, one of the electric railway systems in Ohio shows that, due to consolidations, in less than four years' time the indebtedness was increased from $24,000 to $44,000 per mile, with corresponding increase in capital stock. Further, the Bureau of Railways of Pennsylvania, in its recent report, draws a comparison between the electric railways in that State and the Pennsylvania Railroad system east of Pittsburgh.

The total electric railway mileage is given at 2175 miles, and the total Pennsylvania Railroad mileage at 5787 miles. The total capitalisation of electric roads, including operating companies and leased lines, amounts to $100,694,919 funded debt and $180,499,557 capital stock, or a total capital account of $281,194,476. The funded debt of the Pennsylvania Railroad is given as $89,-000,000; its capital stock as $203,000,-000, or about $290,000,000 total capital account, or about the same as electric roads, while the earnings of the Pennsylvania Railroad in one year were $101,329,795, against $29,001,741 for the electric, or more than three times as great.

Comparative figures have been published covering a period of about ten years for the States of Pennsylvania and Massachusetts which show that in Pennsylvania the capital stock has increased 500 per cent., debt has increased about 680 per cent., and the gross earnings increased about 170 per cent., while in Massachusetts these figures are 129 per cent., 225 per cent., and 136 per cent., respectively.

It has been argued that electric railways can be operated for a less percentage of their gross receipts than steam railways. This is probably so, as the wear and tear on rails is much greater with locomotives, due to the pounding of the reciprocating parts, than on electric roads. The method of generating power in electric central stations is far more economical than in locomotives, while the sub-station method of distributing power to the cars has made possible the construction and operation of long-distance lines; but the wear and tear on the cars is probably greater on electric roads than on steam roads, owing to the fact that there are more frequent stoppages and a great amount of electric machinery on each car to keep in repair.

Many interesting comparisons have appeared from time to time giving the earnings of electric railways, as compared with steam railways.

The Interstate Commerce Commission examined into this matter a short

time ago, and reported that the average operating expenses of steam roads in the United States are 64.6 per cent. of the gross earnings, while those of interurban electric lines are only 54 per cent. A number of individual cases are likewise cited which give this same ratio for electric lines competing with steam railways, and shows that electric roads are operated from 10 to 15 per cent. cheaper than competing steam lines. These figures apply to passenger traffic, while interurban electric roads handling baggage, express matter and freight are reported as handling this for about 21 per cent. of the gross receipts.

It must be remembered, however, that the interurban roads referred to do not run parallel with steam roads for any great distance. Still, in many cases the distance has been sufficiently great and the loss to the steam roads has been sufficiently large to make the latter roads endeavour to recover, through rate wars, the travel they have lost, and the curious consequences of such rate wars have been frequently disastrous to the steam railway through the loss of both passenger and local freight business as well. It must be remembered that the usual rates charged for passengers on steam railways average fully 2 cents per mile, while the rates on the electric road average about 1¼ cents per mile, which means that steam railways must cut their passenger rates in half to meet the normal rates charged by the electric roads, with the advantage in favour of the electric roads as affording the most desirable method of travelling.

The average earnings from passenger travel on steam roads vary greatly, those of the New York, New Haven & Hartford Railroad being probably the greatest, at $10,400 per mile. The New York Central earns about $7000 per mile, the New Jersey Central about $4000 per mile, the Norfolk & Western $1400 per mile, the Illinois Central about $1900 per mile, and the Southern Railway about $1400 per mile. It is, therefore, reasonable to assume that the average passenger earnings of steam railroads throughout the country do not exceed $2500 per mile, as compared with about $3800 on interurban electric roads, some of which latter, however, are reported as being as high as $5500 per mile.

It must be remembered that the electric railway, both city and interurban, has come to stay; its development, however, has been so rapid that a tendency to overbuild has been created. Inflation in its securities has undoubtedly taken place even when the construction has been accomplished at an increased cost. The probabilities are that many railways have not made ample provision for maintenance, and there is no doubt that the high speed with which the cars are operated over highways makes danger from accidents very great.

Where such conditions exist, some reorganisations must necessarily follow, and the history of steam railwayre organisations must repeat itself to some extent with electric roads before they can be put on a permanently sound basis. On the other hand, it must likewise be remembered that electric railways are usually built through territories containing a dense population, that the service is frequent, and that increased opportunities for travel induce a desire to travel. The tendency of the people is to use cheap methods of transportation, both for business and pleasure, and to this extent electric railways are the means of increasing both business and social intercourse.

Further, electric railways can probably be operated as cheaply, if not more cheaply, than steam railways, while the earnings per mile from passengers are usually greater than on steam railways. Investors should, therefore, use the same caution in purchasing street railway securities that they would in purchasing a horse or a piece of real estate. Make sure that the title is sound, that the property has been conservatively organised and is being conservatively managed, and that the territory is sufficiently populous to make the road pay. Always keep in mind the fact that each car must carry about three passengers at five cents each for each mile the car runs in order to pay the expenses of operating the car.

STEAM WAGGONS FOR COMMERCIAL USE

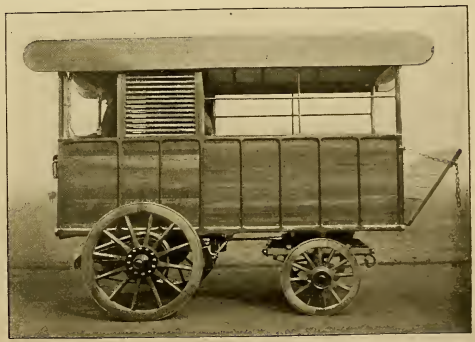
By R. G. L. Markham, M. Inst. M. E.

A LANCASHIRE STEAM MOTOR COMPANY'S LARRY RUNNING ALONG A FLOODED HIGHWAY

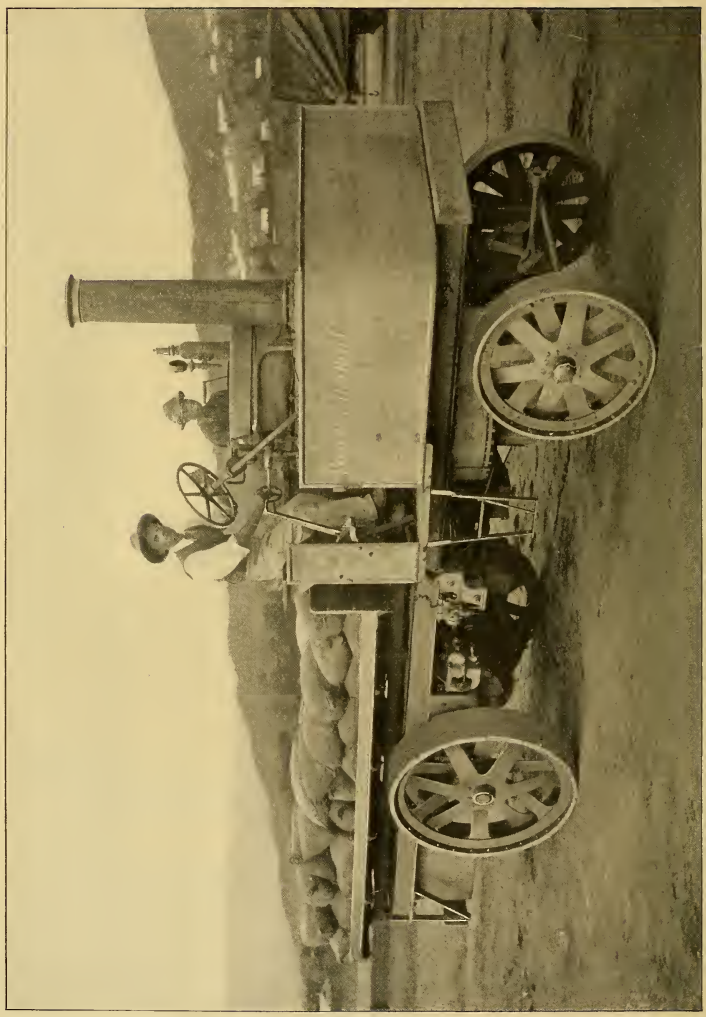
IN these days of scientific progress we are so accustomed to move with the times—rapidly,—that events of most vital importance and most far reaching discoveries meet with but little of the sensational comment which would have heralded matters of far less moment half a century ago.

It is, therefore, perhaps not surprising that the recent May Day parade of motor waggons on the Thames Embankment in London should have provoked comparatively little comment from the press and public in general. Yet, did not this parade mark an epoch in our advance along the line of mechanical replacement in all the processes of our commercial existence? It was probably the first time in history that so many mechanically propelled vehicles for the carriage of goods had been collected together, whether for show, for trial, or for other reasons; also this meeting was a May Day parade at which prizes were awarded to the drivers of the best-kept "turn-outs." This implies that trials have served their purpose and are things of the past, that even novelty is passing, and that the steam waggon is an admitted factor in business, and that it has now become merely a matter of which vehicle is kept in best order.

Comparatively very few firms are engaged in building steam waggons; fewer still have any considerable output as yet; and not all of these have vehicles to represent them in London. Yet only one week's notice was sufficient to bring together a proportion of those working in the London district which reached the respectable total of over thirty vehicles, and—note it well—every one of them of British manufacture from first to last. This is surely sufficient reply to those who say that the industry is still in its experimental stage and that the steam waggon is not yet a commercial success. There is no longer any doubt that the steam waggon—the only type of auto-vehicle which has hitherto



A THORNYCROFT STEAM VAN OF 1895.—PROBABLY THE PIONEER OF STEAM WAGGONS OF THE PRESENT DAY



A THORNYCROFT COLONIAL WAGGON IN SOUTH AFRICA, WITH A LOAD OF GOLD CONCENTRATES

A STEAM MOTOR AMBULANCE, MADE BY THE THORNYCROFT STEAM WAGGON CO., LTD., LONDON, FOR THE METROPOLITAN ASYLUMS BOARD

proved itself satisfactory for considerable loads—has taken its place betwixt horses and railways in the transport of merchandise.

In the majority of cases, of course, the steam waggon cannot compare with the railway in either speed or economy, but there are also many occasions when the road engine can compete very successfully with its fellow of the rail. The cost of railway transport is made up of conveyance rates and terminal charges, and it is evident that for short distances the latter, being practically constant, must bear an undue proportion to the former when estimated as part of the total cost per ton-mile. The steam waggon, on the other hand, practically eliminates all terminal charges, and delivers straight from producer to consumer, or as the case may be, without intermediate break of bulk. From a consideration of these points it will be evident that over distances which are within its ordinary day's work, the steam waggon may well prove superior.

But it is in replacing that expensive animal, the draught horse, that the function of the steam waggon chiefly lies, owing to its relative economy in use. And to this question of economy is attributable, at least in part, the fact that the mechanical goods waggon has had a much harder fight for existence than the lighter pleasure automobile, and is perhaps the hardier for the struggle. In the case of the pleasure vehicle France had already given us a lead; we had at first merely to import, imitate, and improve. The steam waggon, on the other hand, besides starting comparatively late, has been entirely evolved in Great Britain without any satisfactory precedent. That, however, is only a small part of the matter, for whereas the purchaser of a pleasure automobile looks to his increased enjoyment for remuneration, the case is far otherwise with the commercial autovehicle, and a man must first be convinced that he will obtain some real economy and satisfactory return for his outlay in the form of money before he will invest in a steam waggon.

To many people the comparatively high prime cost is enough to deter them from further consideration, and the matter is therefore by them never fairly understood. Perhaps the following fig-

OVERHEAD TRAMWAY WIRE REPAIR WAGGON, MADE BY MESSRS. T. COULTHARD & CO., LTD., PRESTON

ures may serve a useful purpose by enabling each prospective user to estimate for his own case the possible economy likely to arise. It is impossible to take an exact case as the figures must vary with different conditions, and makers will assign varying values to the several items of annual expense of their own steam waggons; but the figures given here may be accepted as an index. First of all it must be assumed—and it is a fact borne out now by some years of experience—that one steam waggon of usual size and construction replaces in the work it performs three two-horse drays or vans. Then as regards initial expense, the steam waggon may vary in price from £550 to £700; so, say it costs £650.

The equivalent in horses and vans would be, say,—

3 wagons at £65	195	0	0
6 strong horses at £60	360	0	0
6 sets harness at £7½	45	0	0
Total prime cost	£600	0	0

Probably most careful owners would include one spare horse in six. The prime cost, therefore, is approximately the same in the two cases. Assume it so, £650, for the sake of argument, and a comparison of working expenses will then be the test of the economy to be derived from the new method of transport.

The annual expense of the horse system may be set out thus:—

Interest on capital, 4 per cent	26	0	0
Depreciation, 15 per cent	97	10	0
Fodder and bedding	218	0	0
Shoeing	28	0	0
Repairs (waggons and harness)	36	0	0
Horsekeeper, at 25s	65	0	0
Veterinary surgeon	7	7	0
Rent, rates, etc	78	0	0
Drivers, at 25s	195	0	0
Total annual cost	£750	17	0

For the steam waggon the annual expense may be taken as follows:—

Interest on capital, 4 per cent	26	0	0
Depreciation, 15 per cent	97	10	0
Maintenance and repairs	60	0	0
Rent and rates	15	0	0
Oil and stores	10	0	0
Driver at 35s. a week	91	0	0
Lad, at 20s. a week	52	0	0
Total annual cost	£351	10	0

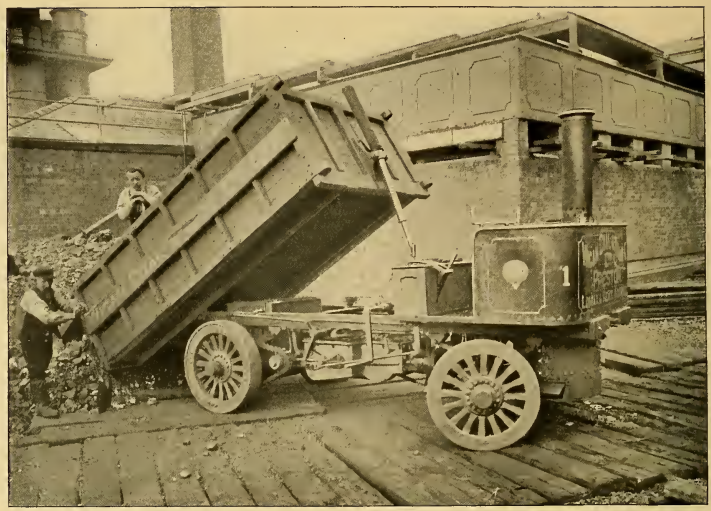
Thus it will be seen that a steam waggon costs about the same as a set of horses and vans doing the same amount of work, while the annual expense of this service is in the latter case less than half that in the former. These figures may be considered as mere theory, but the makers can produce statements from users of their vehicles which bear out the above deduction and besides testify to a saving of time and in some cases to an actual extension of business directly attributable to the adoption of steam waggons.

The steam waggon of to-day in its general efficiency and economy of working is much superior to what it was a few years ago, but this result has not been brought about without great efforts and the expenditure of considerable sums of money on the part of those engineers and others who have devoted themselves to the task. Among others, and not least, the Self-Propelled Traffic Association of Liverpool is deserving of much credit for the service it has rendered to the industry at large and to the public generally, by the promotion of trials for commercial steam waggons. These trials, held in 1898, 1899 and 1901, have been ably and impartially conducted, and the severity of the tests imposed have ensured excellence of design and workmanship, while they also indicated a practical standard of requirements to which these vehicles must attain if they are to come into general use for commercial purposes.

Without going into the reports of these trials, the general summing-up of the official judges is worth quoting. After the 1899 series they said that "the hill-climbing powers of the vehicles were greatly superior to those of horse-drawn vehicles," and that "the general control, starting, steering, and stopping amongst traffic was superior to that of the best types of horse vehicles."

In their report on the 1901 trials the judges confirm their remarks and add that "the powers of control possessed by the driver of a motor vehicle are particularly evident in manœuvring and on hills. In descending steep hills the normal speed can be maintained with-

CARRYING SUGAR CANE IN MAURITIUS IN STEAM WAGGONS MADE BY THE THORNYCROFT STEAM WAGGON CO., LTD.



ONE OF THE WAGGONS OF THE LANCASHIRE STEAM MOTOR CO., MANCHESTER

out locking a wheel or using a slipper." The judges also report that they "consider that reliance may be placed upon the systems to which gold medals have been awarded, for regular employment in general haulage operations where due care and supervision are exercised."

That was two years ago and the Liverpool association then considered their labours at an end so far as trials of heavy commercial autovehicles were concerned; but the makers have not rested, and steam waggons of to-day, though not altered in general design, are much improved in detail and, therefore, in general trustworthiness and immunity from breakdown.

The difficulties to be overcome in the construction of a locomotive to run satisfactorily on common roads are not so generally understood as they should be, and a great appreciation of the many requirements of such engines would lead to a better comprehension of their necessarily high prime cost. At first sight a not unnatural comparison is often drawn with the railway locomotive, but a moment's consideration will show that this is manifestly unfair. The track upon which the latter runs is almost ideal, being smooth, hard and unyielding in all weathers, and in consequence this engine gains practical immunity from the incessant vibratory strains experienced by the road locomotive on even the very best of roads, to say nothing of the constantly recurring shocks due to stones and other obstacles or inequalities of surface.

The railway engine has to surmount hills, of course, but what are they? Probably nothing greater than an incline of 1 in 50 and very seldom that. The makers of steam waggons, on the other hand, are very frequently asked for vehicles capable of taking a full load up 1 in 10, and occasionally inquiries from abroad stipulate hills considerably stiffer even than this. As regards the tractive effort required on common roads, the following table is instructive. The relative figures there given, obtained as the result of many experiments by several authorities, though well known to those whose business lies that way, may appear rather astonishing to others:—

Road Surface	Relative Resistance	Road Surface	Relative Resistance
Rail	10	Macadam, good	50
Asphalt	15 to 29	Macadam, ordinary	60 to 80
Wood pav'g	20 to 30	Macadam, soft	97
Setts, good	35	Cobbles	60 to 130
Macadam, best	43	Sand road	up to 360

It will be seen that traction even on the best macadam road requires more than four times as much effort as upon a railway; and since a road engine must be capable of negotiating any reasonable road it may encounter, it is evident that for the same load it should be at least ten times as powerful as a railway engine. But even this is not sufficient, for it makes no allowance for hills nor for very sticky, muddy roads, in both of which cases the tractive resistance is increased, and in the latter case very considerably so.

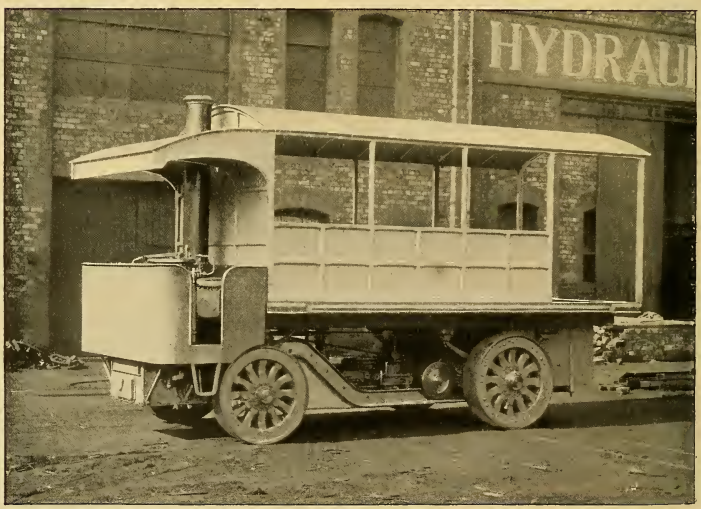
According to present practice, steam waggons for home use are fitted with engines and boilers capable of developing from 20 to 30 horse-power. The man who has nothing to do with engineering is very apt to assume that this is equivalent to so many horses and, therefore, to conclude that the steam waggon is amply, if not in fact excessively, powerful for every possible case. This is very misleading, for while the mechanical horse-power represents a definite amount of work, the power exerted by a horse is a very varying quantity, dependent upon the time during which the animal is required to exercise that effort. In a limited time an engine of 20 horse-power will not exert as much power as 20 horses *can* exert in pulling a load, nor anything like it.

Experiments have been made with a view to obtaining some idea of the power a horse was *momentarily* able to exert, and it was found that for a short effort he proved himself the equal of an engine of 14 mechanical horse-power! This may appear startling, but it is, nevertheless, a well authenticated fact. It is a common sight to see two, or even three, horses pulling a comparatively light load out of a very soft sticky place, say, where building operations are in progress. It might have been thought that a steam waggon of 20 horse-power should easily be able to do the same. But apart from the fact that this power applied at the wheels of the steam waggon is not nearly so efficient as would be a direct pull of like amount, consideration of the effort a horse is able to exert in such a case should carry conviction that the steam waggon would probably be very far from extricating itself. It should not, therefore, be astonishing that these light road engines should occasionally stick when a particularly soft track is encountered, even though they be entirely satisfactory upon a hard road. The much more powerful traction engines with their broad wheels do the same.

Some time ago a remarkable case having particular bearing upon this point came under the writer's notice. A traction engine, crossing the city in the early morning, stuck for a considerable time in a soft place where the road had been remade after laying mains, and all the efforts of the attendants failed to move it. A steam waggon, coming by later, was harnessed to it, and, being on firm ground itself, by the direct pull it was able to exert, suc-

A TRADESMAN'S DELIVERY VAN, MADE BY CHAS. T. CROWDEN, LEAMINGTON

A STEAM MOTOR DRIVEN FIRE ENGINE, MADE BY CHAS. T. CROWDEN, LEAMINGTON



ONE OF THE WAGGONS BUILT BY MESSRS. C. & A. MUSKER, LTD., LIVERPOOL

ceeded in extricating the unfortunate traction engine amid the cheers of the assembled crowd.

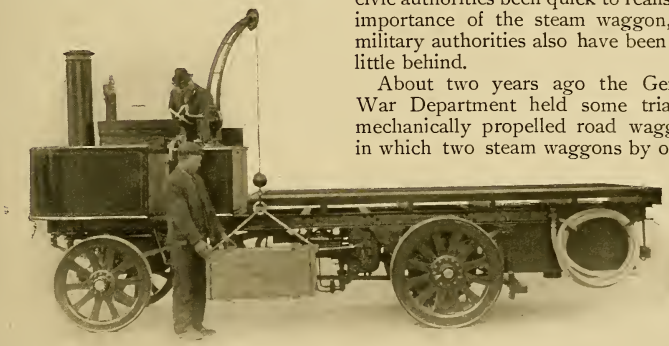
The uses to which steam waggons are, and can be put are many and various. Probably the largest users are brewers who, with their constant and heavy loads from brewery to depot and with return loads of "empties," are able to appreciate to the full the economical benefits of this method of transport. Millers also constitute a considerable part of steam waggon makers' clienteles; and the vehicles find spheres of usefulness and economy in many other directions. Steam waggons are used by railway companies, for both goods and passenger traffic; by contractors, coal merchants, engineering firms, water works companies, gas companies, timber merchants, mineral water manufacturers, co-operative societies, calico-printers, paper makers, furniture removers, and many others.

They have been adopted for municipal purposes by many of the London and provisional corporations with a very marked degree of success. A somewhat special type of vehicle has been designed for this class of work, and is provided with a tipping body for refuse collection, as well as with a water tank of large capacity for road watering, the two being readily interchangeable on the one machine. By this means the vehicle is worked to its full capacity, and considerable economy is effected.

In some districts of London where these steam waggons have been in use for two or three years, they are worked sixteen hours a day, and the economy over the old method of horse-drawn dust carts and water vans is reported as about £175 per annum by the use of each machine. Another feature of these municipal motors is the addition of a revolving road-sweeping squeegee or broom, driven by the machine itself, in combination with a watering waggon. The sweeping arrangement is easily removed and does not interfere with any of the other uses of this class of vehicle.

Not only have commercial men and civic authorities been quick to realise the importance of the steam waggon, but military authorities also have been very little behind.

About two years ago the German War Department held some trials of mechanically propelled road waggons, in which two steam waggons by one of the leading British makers took a prominent and satisfactory part. Probably everyone knows that the British War Office held some very exhaustive trials at Aldershot in December of 1901. These tests were not confined to the roads, but included some extremely severe cross-country work, and many points besides actual running results were taken into account in making the awards. The waggons, by two different makers, to which the first two prizes were awarded, were purchased by the War Office and sent off at once to South Africa, where they served during the



ANOTHER TYPE OF THORNYCROFT WAGGON

final stages of the Boer war. The authorities on the spot were so satisfied with their performance, and convinced of their utility, that a number more were ordered. These, however, were not ready before the cessation of hostilities, and they have consequently been retained at home for the purpose of carrying out further experiments. The India Office has followed the lead of the War Office, and their steam waggons were to be seen in Delhi at the time of the Durbar. The pacification of South Africa and the fact that steam waggons are already at work there is constantly bringing in fresh orders, with the result that a special type of waggon is now being introduced to meet colonial and military requirements.

Although the steam waggon is a comparatively recent institution, its general utility is so widely recognised that it is rapidly becoming ubiquitous throughout the British Empire, and may even now be found, among others, in such widely diverse places as Cape Town, Johannesburg, Pretoria, Durban, Pietermaritzburg, Port Elizabeth, Breuersdorp, Swaziland, Lourenco Marques, Gold Coast, Congo Free State, Mauritius, Bombay, Delhi, and other parts of India, Ceylon, Burma, Singapore, Borneo, Australia, New Zealand, the United States, Germany, France, Italy, Spain, and Portugal.

These vehicles are used for a large variety of purposes by a diversity of authorities, public companies, and private firms, including corporations, a harbour board, railways, a tramway company, gold mines, ruby mines, sugar estates, brewers, millers, timber owners, haulers, carriers, etc., etc.

It should be a pleasant national conceit that British brains and hands have practically initiated this new industry, and have prosecuted it with such success that British steam waggons may now be found, as this list will show, in almost every corner of the world. There are now perhaps a round dozen of makers of steam waggons of one form or another; some have been building for several years, others have only lately commenced, and from the statements of the leading makers who have turned out from 50 to close on 300 vehicles in the several cases, it may be computed that the aggregate output to date is little short of 1200 vehicles of all types. The makers' difficulty now is not so much to build a waggon that shall prove satisfactory and sell it, but rather to construct them quickly enough, for, even with a rate of output of from 4 to 12 a month, the best-known firms are still several weeks behind their orders.

There is no room in an article like this to discuss different designs, or to go fully into details of matters attending the use of these vehicles, but the accompanying illustrations are fairly representative of some of the different types of waggons and the purposes for which they are used. For the rest, the several makers are always willing to advise as to the probable usefulness of a steam waggon in particular cases.

In conclusion it is satisfactory to note that, though it has been argued that other nations have had the lead of Great Britain in the manufacture of automobiles for pleasure purposes, in the case of steam waggons for heavy goods transport Britain has been from the first, and is now more than ever, *facile princeps.*

THE RAILWAY TOWN OF CREWE

PART II.

THE HOME OF THE LONDON & NORTH-WESTERN RAILWAY WORKS—THE LARGEST IN THE WORLD

Part I of this article appeared in the September number.

By Charles S. Lake

THE tender shop is the next to be visited. This is one of the finest shops in the whole of the works. It is 530 feet long and 121 feet wide, and in it all new tenders are built and old ones repaired. The latest pattern tenders are of 2000 and 2500 gallons capacity, and all are fitted with Ramsbottom's pick-up apparatus for taking up water from troughs whilst running. Wooden frames are used for tenders on the London & North-Western Railway. Mr. Webb was strongly opposed to the practice of hauling heavy dead-weight loads about the country in the shape of tenders weighing anything up to 45 tons, as is done on some lines, and he looks upon them in the light of what they really are,—vehicles which ought to be kept as light as possible.

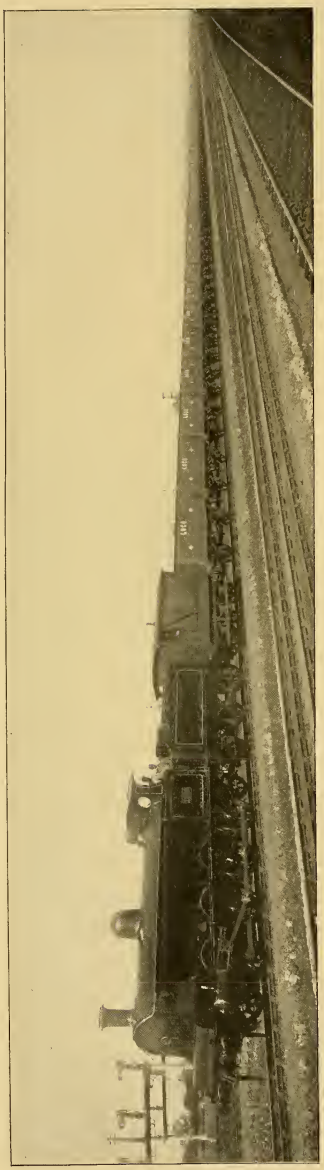
The trough system and light-weight tenders are coming gradually into vogue on many British railways at the present time, and the writer ventures to predict that this combination will be found to be highly preferable to the cumbrous 6-wheel or double-bogie tenders, the weight of which, loaded, is equal to about 75 per cent. of that of the locomotive itself. All the tanks for the tank-engines also are made in this shop.

The shop is fitted with six 10-ton electric travelling cranes, and also lathes, drilling, shaping, punching and shearing and other machines, all driven electrically. The new 20-ton "Loco" coal waggons (a long train of which, hauled by one of the latest four-cylinder compound goods engines, is shown on the next page) are built in this department.

In the brass foundry, as in the iron foundry, much of the moulding is done by machines, and plated patterns are used. There are two large melting furnaces for the heavier castings, and also ranges of crucible furnaces, the gas for these being obtained from two producers located just outside the building. Galvanising is carried out in an adjacent building. The metal baths hold from 50 to 60 tons.

Adjoining the galvanising shop is the coppersmiths' shop. Here are made all the copper pipes used upon the locomotives and for other purposes, head lamps for engines, and a variety of small work required either in tin or copper. One end of the shop is devoted to the cutting, lengthening, and testing of boiler tubes. The tubes, after being taken out of the boilers under repair, are brought to this shop, where they are first placed in large revolving rumblers which remove all the scale. The damaged ends of the tubes are next cut off and new pieces brazed on, to bring the tubes up to the required length for reuse. The tubes are then tested by water pressure to 400 pounds per square inch, and afterwards are stacked up until required.

The signal shop, which comes next, is a building 280 feet long and 85 feet wide, and is fitted with various lathes, drilling, planing and screwing machines, saws, general joiners, etc., all driven by a 48 H. P. gas engine. The average



A TRAIN OF SIXTY 20-TON COAL WAGGONS DRAWN BY AN EIGHT-COUPLED FOUR-CYLINDER COMPOUND ENGINE

output per week of this department is about nine sets of signals complete, besides other work connected with signalling.

Mr. Webb's system of interlocking, which he designed as long ago as 1874, has proved so successful that it has remained in operation until the present day in practically its original form, only minor alterations in matters of detail having been carried out. The largest interlocking apparatus made at Crewe up to the present is that for the double signal cabin at London (Euston), which contains 288 levers.

The point rodding is of special channel section designed by Mr. Webb, and is jointed by fish plates. It is rolled at Crewe, about 6000 yards of it being turned out monthly. In this department the Webb-Thompson electric staff apparatus for single-line working is also manufactured. This system has been largely adopted by railway companies both at home and abroad.

Employment is found for a large number of lads in the nut and bolt shop; in fact, nearly all the machinery in this department is manipulated by apprentice hands, in consequence of which fact it is known throughout the works as the "nursery." The shop is equipped with numerous lathes, shaping, slotting and screwing machines, bolt and nut forging machines, nail and spring-making machines, and various other tools.

A special machine is in use which does away with the shaping process otherwise necessary in the manufacture of finished or bright nuts. Both nuts and bolt heads are produced with equal facility by means of this machine, which stamps the required articles out of the solid and leaves them, so far as the bolt heads are concerned, finished articles, whilst all that remains to be done in the case of the nuts is to tap them in the ordinary way.

The next place reached after leaving the nut and bolt department is the wheel shop. Some very fine machinery is to be found in this shop, including lathes capable of turning up to 8 feet 9 inches in diameter, also axle and tire lathes, a crank "nibbling" machine (the too

holder of which carries 160 cutting tools at once), slotting, planing, boring and milling machines, and frame and piston-rod grinding machines. There are also hydraulic presses for forcing wheels on to their seats and displacing them, putting in crank-pins, etc. Two 4-ton electric travelling cranes are provided, and the whole of the machinery is driven by two gas engines each of 30 horse-power.

Some heavy work is done by the various machines in the wheel shop. Engine frames 1 inch thick are slotted in batches of ten, piled one above the other, and suitably clamped together. These frames are afterwards drilled, four at a time, all the holes being drilled by the aid of templates, with hardened steel bushes to insure accuracy. Stacks of eleven smoke-box fronts are slotted simultaneously.

The last shop of all to be visited in the steel works is the paint shop, 350 feet long by 208 feet wide. This has several "roads" for the accommodation of engines which are undergoing the smartening-up process of being painted. Usually about 100 engines are to be found in this shop at one time awaiting their turn to be painted and lined out, and also to receive their name-plates (if passenger engines with tenders), and, in the majority of cases, the London & North-Western Railway Company's coat of arms, which is placed on the driving-wheel splashers of all engines, with the exception of the "D.X" type and eight-coupled, three and four-cylinder goods engines and all the tank locomotive types.

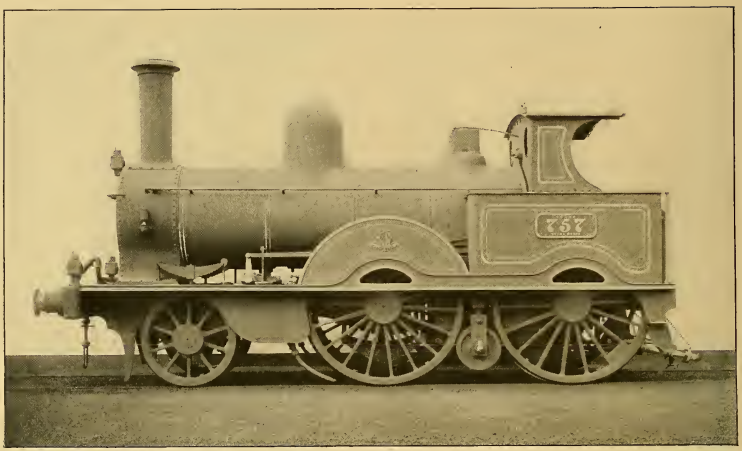
In this department also are stabled two or three very interesting locomotives, which are rarely, if ever (with one exception), taken outside the building at the present time. One of these is "Triplex," an old Allan "single," with triple-expansion cylinders. The high-pressure cylinder is on the outside of the frames on the left-hand side of the engine, and the intermediate cylinder occupies a similar position on the right-hand side, whilst the low-pressure cylinder is situated between the frames, as in Mr. Webb's three-cylinder compound engines. Another notable locomotive is the old "Cornwall," which has the largest pair of driving wheels extant, viz., 8 feet 6 inches on tread. This engine is still employed on the Liverpool and Manchester expresses, which cover the distance of thirty-two and one-half miles in forty minutes.

No. 757, a four-coupled passenger locomotive of Mr. Ramsbottom's design, is also to be seen in the paint shop. This engine had been fitted by Mr. Webb (as an experimental measure) with a special device, known as a combined steam brake and coupling gear, which, as its name would lead one to suppose, entirely does away with the ordinary form of coupling-rods, brake blocks, and gear.

This engine is shown on page 522. A disc is provided between the wheels, free to revolve on its own axis and suspended from a steam cylinder in such a manner that in its normal position it hangs clear of both wheels, and the engine is then to all intents and purposes a "single" engine; but when it is to be used as a coupled locomotive the disc is raised by means of the steam cylinder, and is brought in contact with the wheels, serving as a friction gear to impart motion to the second wheel. When using the disc as a brake, it is simply raised by the steam cylinder with sufficient force against the wheels after steam has been shut off from the engine cylinders.

Upon entering the Deviation Shops from the western end, the first department to be inspected is that known as the Testing Shop. Not only are all the boiler plate tests carried out in this department, but also all chains used throughout the line, from the massive types employed on the heavy cranes to the light varieties used for lifting sacks at the goods warehouses and other similar purposes, are here subjected to the most rigid examination before being passed out into service.

Chains of every description are sent here three or four times a year for examination, and records of the results obtained are carefully kept, so that it may be possible to ascertain, by referring



PASSENGER ENGINE FITTED WITH MR. WEBB'S COMBINED STEAM BRAKE AND COUPLING GEAR. WHEN USED AS A COUPLING GEAR, THE DISC BETWEEN THE DRIVING WHEELS IS RAISED BY STEAM POWER UNTIL SUFFICIENT CONTACT IS OBTAINED TO COMMUNICATE MOTION FROM ONE WHEEL TO THE OTHER

to the registers, what the age and condition of a chain was at any given date.

Following upon this important shop is the Outdoor (or Outstation) Department. Here it is that all the spare machinery connected with the water supply, required at all parts of the company's system, is kept in stock, ready for use. Among other things, there is a travelling pumping apparatus, consisting of a locomotive-type boiler and all the necessary appliances, the whole mounted on a six-wheeled platform truck, kept in constant readiness to proceed at the shortest notice to any station or yard at which the permanent pumping apparatus may have become disabled. The "traveller" remains on the scene and performs the duties of the fixed plant until the latter has been repaired.

The Millwrights' Shop, a continuation of the Outstation Department, is the largest and busiest section of the Deviation Works. It might very well be termed the "general engineering" establishment of the company, for there it is that all the engines and pumps, cranes, electric dynamos, gas compressors, crankshafts and other work for the London & North-Western steamers are fitted and repaired. In addition to this work, all the repairs to the machinery and shafting at the Crewe Works are made in this department.

As illustrating the widely divergent nature of the work done, it may be mentioned that it is not at all infrequent to see chaff-cutting machines under repair within a few feet of where a 50-foot turn-table is being constructed. The making and re-cutting of files is also carried on in this department,—in a portion of the building specially set aside for the purpose. Just outside the shop a steam sand-blast apparatus for file-sharpening purposes is provided.

At the further end of the Millwrights' Shop the dynamo and electrical department is situated. All the dynamos and heavier description of electrical apparatus are made there, whilst all the smaller electrical fitting work is carried on in a gallery, where about 100 men are employed.

A partition separates the gallery electric department from the joiners' shop. The latter is a large, well lighted apart-

ment equipped with all kinds of woodworking machinery. The first thing to claim the attention here is the manufacture of artificial limbs. When any servant of the company, who has been so unfortunate as to lose any of his limbs or any part of one of them, has reached a state of convalescence, particulars of his requirements are duly noted and the patient himself is taken to the joiners' shop to be measured. Within a week or so thereafter he is provided with an artificial foot, arm, or leg, according to the nature of his requirements.

All the woodwork required by the company is supplied from the joiners' shop, embracing such items as roofing, shed doors and portable huts, large numbers of the latter being made for the line generally and used for such purposes as booking offices, waiting rooms, lamp rooms, coffee taverns, goods storage and horse shelters; also doors, windows and other things too numerous to mention. Some idea of the work turned out of this department may be gathered when it is stated that about 5¼ million superficial feet of timber are used up in a year. There are no driving belts in this shop; each machine is independently driven by an electric motor.

In the basement under the joiners' shop the leather department is situated. There all the leather bags for water columns are made, also the driving belts used throughout the works. A specialty of this department is the manufacture of cup leathers for pumps and hydraulic presses throughout the system. The shop is well supplied with sewing, cutting, and stamping machines.

The electric power station, containing the plant used for lighting the locomotive offices and the whole of the Deviation Works, and also for the purpose of driving the machinery in the latter, is next in order. There are four sets of high speed engines, with dynamos to match, in this station. Steam is supplied by three Babcock & Wilcox boilers, one of which is fired entirely with scrap wood, odds and ends, collected from the various machines in the joiners' shop and the sawmills.

Before the latter of these two departments can be entered, it is necessary to pass through the timber yard. A small forest of timber of all descriptions is stored in this place, where, too, a fire engine is stationed, and a watchman is constantly in attendance. There is electrical communication between the fire station and each individual shop in the works.

The Sawmill is fitted with a very large band-saw capable of severing logs of 6 feet diameter, and also with a number of circular and frame saws, and with several planing and other machines. All the sawdust from these is allowed to fall into troughs, and is conveyed from there by means of continuously running endless belts moving in wooden channels to the cellar below, from which it is carried by belting to an outlet, below which sacks are held to receive it. When filled, these sacks are tied up and despatched to various centres on the company's system, there to be used for a variety of purposes, principally for scattering on the floors of cattle loading pens, stables, etc.

A separate department is devoted to the preparation of the oak keys for the permanent way. These, after having been roughly proportioned, are placed in a drum containing a quantity of black lead, the drum being revolved until the keys have become entirely covered with the lead. They are then taken out and passed through suitable dies, to ensure of their all being of equal dimensions when finished, after which they are placed in stock, to be used up as required.

The machinery in the sawmills will, within a comparatively short period, have been adapted to electric driving; it is being converted to that method as rapidly as possible.

The Old Works, which is devoted entirely to the purpose of repairing locomotive engines, consists of four erecting shops, a fitting and turning shop, axle box and spring shops, forge, smithy, and stores. The smithy contains 117 smiths' fires and nineteen steam hammers, ranging in weight from 2½ cwts. to as many tons. There is also a Thompson electric welder of about 40

THE COMPANY'S HOSPITAL IS EQUIPPED WITH EVERY CONVENIENCE FOR DEALING WITH CASES LIKELY TO REQUIRE ITS SERVICES

horse-power, which is constantly employed in welding up tie rods, injector rods, hand railing and other work of a similar description.

Large numbers of engine parts in a rough state are brought to the Old Works from the Steel Works, including spring steel, coupling and connecting-rods from the forge, and cylinders, horn blocks, axle boxes, and other iron and brass castings from the foundry. The lighter articles and "finished work" are taken direct to the fitting shop. The principal feature here is the immense amount of work now done by milling machines but which formerly was planed.

The parts on leaving the fitting shop are ready in every respect for building into the engines in the erecting shops. All the work is finished to standard gauges and templates, so that perfect interchangeability is secured. Mr. Webb was a great believer in the practice of standardising engine details, and he applied this principle, as far as was possible, to several different classes of engines.

No. 1 erecting shop was one of the first buildings to be erected when the Crewe Works was established in 1843. The old gateway and clock tower, always a distinguishing feature of this shop, still remain as originally built. The shop is used principally for repairing passenger and goods tank engines, and is fitted with all the necessary cranes and tools for the purpose.

Each group of repair shops, both here and at the Steel Works, is furnished with boiling pans for removing the oil and grease from the various parts of the engines under repair. The parts are by this means cleansed in a remarkably cheap and efficient manner. The grease is collected and converted into soap.

No. 2 erecting shop is used chiefly for repairing non-compound passenger engines and a few classes of goods engines, and is fitted with travelling cranes and tools similar to those of the other erecting shops. The work carried on in No. 3 erecting shop is principally passenger engine repairs. No. 4 shop is the largest of all, and the greater part of the work is done here. There are here four 25-ton overhead travelling cranes for lifting engines to and from

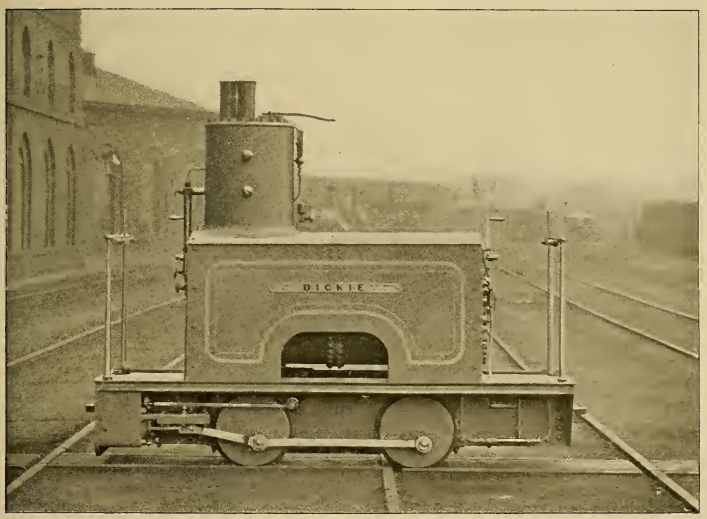
the pits, one crane being used at the leading end and another at the trailing end of the locomotive, each end being slung independently of the other. This method of proceeding enables the slinging operations to be carried out with the utmost ease and nicety. Some of the most remarkable of the many notable London & North-Western locomotives were built in this shop in times gone by. The total number of locomotives built at the Crewe Works from the time of their commencement up to the end of March, 1903, is 4315, as many as 150 having been built within the space of twelve months.

A portion of the Old Works is devoted to the boring, planing, and drilling of locomotive cylinders. These enter the shop in the rough, and are fitted up with covers complete before being sent to the erectors. Piston rods are ground to size by means of emery wheels, not turned, as formerly. During this operation the piston remains in its place on the rod and is used as a pulley for the belt, the complete piston and rod being dead-centered on the lathe, while the emery wheel travels along the length of the rod.

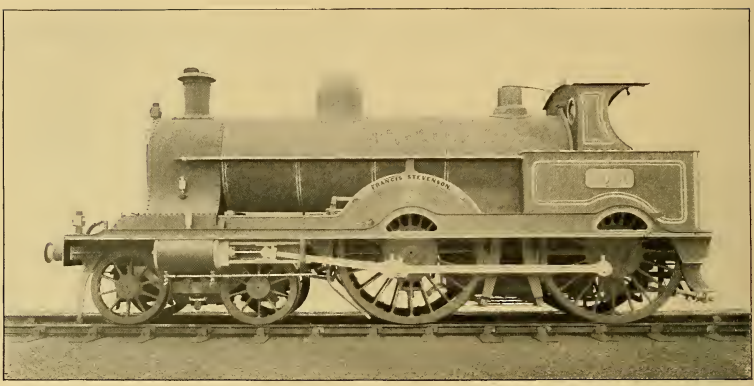
There is also a department in which a large amount of finished brass work is turned out, such as engine whistles, injector details, safety valves and fittings, lubricators, etc. In this shop also the brass name-plates for the passenger tender engines are made.

The stores department immediately adjoins the fitting shop, and there a very complete system of supervision is observed in the method of dealing out materials and engine parts. Nothing whatever can be withdrawn from the stores unless an order, signed by a foreman, is produced, and no one but the store keeper and his assistants are allowed to enter the building. All the standard details of locomotive work most frequently in demand, besides numerous articles required for steam sheds and locomotive stations up and down the line, are stocked in this department.

A visit to the company's hospital,



ONE OF THE TRAMWAY LOCOMOTIVES USED IN THE WORKS



FOUR-COUPLED FOUR-CYLINDER COMPOUND EXPRESS PASSENGER LOCOMOTIVE WITH SEVEN-FOOT DRIVING WHEELS

which is situated within the works' boundaries, concludes the tour of inspection which the author has endeavoured to describe. This building is of pleasing exterior, and is fronted by a large and tastefully arranged garden, encompassed by railings, with neat round stone pillars at the corners. These pillars are built up of old grindstones, incapable of being put to further use in the shops, placed one above the other to the required height. Unless it were pointed out, it is extremely improbable that the visitor would recognise this fact, as the appearance of the material has nothing whatever about it to suggest that it has not been specially prepared for its present purpose. Inside, the hospital is replete with every convenience for dealing with the various cases which are brought there.

Crewe Works is possessed of a motto. This is short, but comprehensive,—"Waste not, want not." Nothing, indeed, is wasted that can possibly be used up in any shape or form. The uses to which some of the leavings from the several departments are put have already been mentioned, as, for instance, the wood dust from the sawmills, the grease from the boiling pans, scrap wood from the joiners' shop, and grindstones for the hospital grounds; but in addition to these all filings, turnings, shearings, and trimmings, indeed sweepings of every description from the various shops, are collected and converted to some useful purpose. Unless this system were adopted and rigidly carried out the waste of valuable material in odds and ends form would amount to something very considerable in the space of twelve months in an establishment such as this.

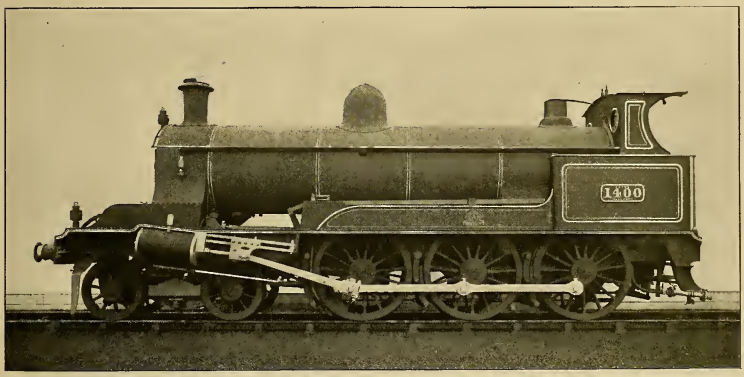
A telephone system connects the offices and all parts of the shops, thus making communication over the large area easy and expeditious. Besides the offices, several of the shops are lighted by electricity, incandescent lamps being used for the former and arc lights for the latter. A fire main, with water at a pressure of 100 pounds per square inch, is laid throughout that part of the works where the more inflammable shops and materials, such as the joiners' shop, the sawmills and the timber yard, are situated.

Electricity for driving the machinery is rapidly superseding steam-power in all the shops. Besides the ordinary 4-foot 8-inch-gauge railway connecting the various parts of the works, there is a narrow-gauge railway,—18 inches,—which traverses every part of the works, its total length being five miles. It is worked by small locomotives (see page 525) which haul trains of strong, low-

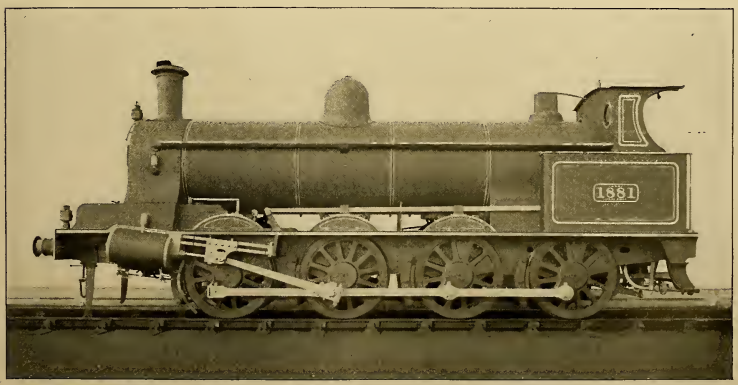
wheeled trolleys, conveying material and finished work from one part of the works to another.

Some of Mr. Webb's latest locomotive designs are illustrated on pages 526, 527, 530 and 532, and on the one opposite. The first one of these is a four-coupled express passenger engine; the second, a six-coupled engine with leading radial truck; whilst the last is an eight-coupled goods engine of powerful type.

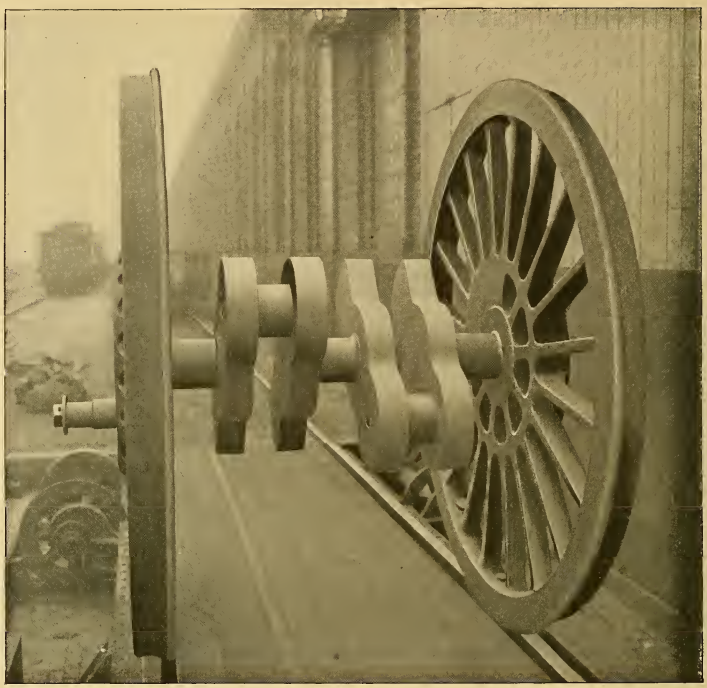
All are provided with four cylinders, compounded on Mr. Webb's well-known system, and the same pattern valve gear is applied in each of the three cases. This is an adaptation of Joy's gear with certain additional features introduced by Mr. Webb for the purpose of allowing of only two sets of gear being used for distributing steam to the four cylinders, all of which drive on to the same axle. Piston valves are used for the high-pressure and ordinary flat valves for the low-pressure cylinders.



A SIX-COUPLED COMPOUND EXPRESS GOODS LOCOMOTIVE



AN EIGHT-COUPLED FOUR-CYLINDER COMPOUND GOODS ENGINE. DRIVING WHEELS 4 FT. 3 INCHES IN DIAMETER



DRIVING WHEELS AND CRANK AXLE OF A SEVEN-FOOT FOUR-COUPLED COMPOUND PASSENGER LOCOMOTIVE OF THE "ALFRED THE GREAT" CLASS, SHOWING THE BOSS WITH RECESSES FOR LEAD FILLING FOR BALANCING

The valve-setting apparatus shown on the opposite page is kept in the drawing office, and by its aid accurate results can be arrived at before any part of the gear is made in the shops.

The coupled wheels of the passenger engine are 7 feet 1 inch in diameter, and are made of steel throughout. In place of the usual crank-shaped centre, a large circular boss, 2 feet 9 inches in diameter, is provided. At the back of this boss a number of recesses are cast, some of which are filled in with lead to form a counterbalance for the high-pressure rods. Bars, 5/8 inch square, are cast into those recesses in which the lead is to be put; these form cores through the centre of the metal, and assist to hold it immovably in place when cold. A pair of driving wheels is shown on this page. It will be noticed that the low-pressure crank webs are provided with extension pieces, so that the whole of the revolving and reciprocating parts are evenly balanced. Mr. Webb informed the writer that one of the engines of this type ran a distance equal to ten times around the world with the loss of only a little over 1 inch, or about 40 per cent., of the total thickness of the tire.

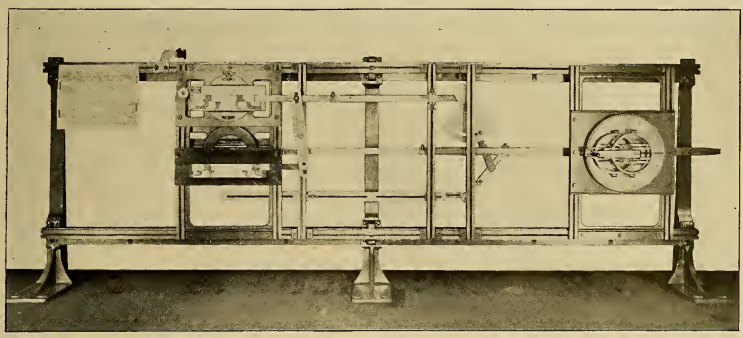
The space between the low-pressure cranks is occupied by a central bearing, carried in a cast iron frame, the rear end of which is bolted to a cross-stay plate situated immediately in front of the fire-box. The low-pressure crank-pins are hollow, as can be seen in the illustration.

The cylinders of the "Alfred the Great" class of engines are,—high-pressure (two), 15" × 24"; low-pressure (two), 20½" × 24"; steam pressure, 175 pounds per square inch; total heating surface 1550 square feet. The weight of the locomotive in working condition is 57 tons 12 cwt. The number of engines of this type owned by the London & North-Western Railway is constantly being increased. Ten have recently been ordered and are now in course of construction at the Crewe Works.

In the new class of four-cylinder, six-coupled goods engines (see page 527) the cylinders are precisely the same as also at work, but the construction of this type has now been discontinued in favour of the four-cylinder pattern.

The other engines illustrated on pages 530 and 532, are the "18-inch" six-coupled goods engines, with 5-foot wheels, used principally on fast goods trains and frequently on the slower passenger trains and the 18 inch × 24 inch six-coupled passenger tank engines with 5-foot wheels and a trailing radial axle. These locomotives are employed in working the heavy suburban and local traffic in the London district and at other congested centres.

The Board of Trade quite recently introduced a new rule making it com-



THE LOCOMOTIVE VALVE-SETTING APPARATUS USED IN THE DRAWING OFFICE

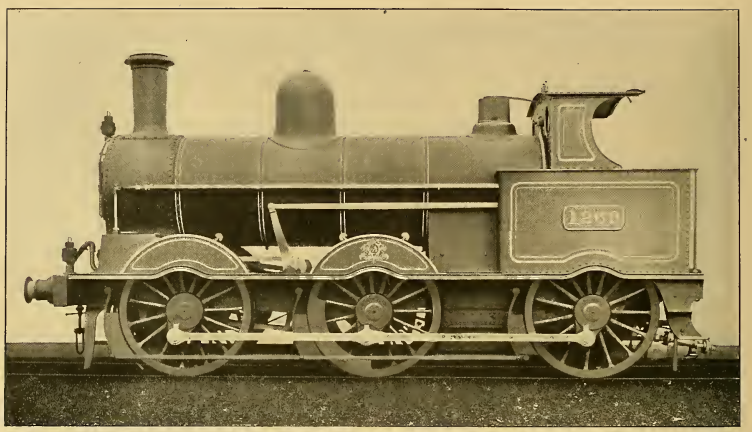
in the express and eight-coupled goods engines, as is also the valve gear. A great saving is effected by this system of adapting such vital details as cylinders and valve gear to those totally separate types of engines, intended for widely different classes of traffic, as it allows of the use of the same drawings, patterns, and templates in each design.

The eight-coupled, four-cylinder compound goods engine shown on page 527 is one of a very numerous class in daily use throughout the company's system.

The wheels are 4 feet 3 inches in diameter, the third pair from the leading end being flangeless. Over one hundred similar engines (but built on Mr. Webb's three-cylinder principle) are

pulsory on the part of all railway companies to provide a gauge-glass, or other means of ascertaining at a glance the height of water in the tenders of locomotive engines without its being necessary for the men to go on to the top of the tender for the purpose. On the majority of railways this order has been complied with by fitting gauge-glasses of a pattern similar to those used on the fire-box fronts; but Mr. Webb considered that the practice of doing this entailed unnecessary expense, and he, therefore, designed, and fitted to all London & North-Western Railway tenders, the very simple device shown on page 533.

This is nothing more than a piece of



A FIVE-FOOT SIX-COUPLED GOODS TANK ENGINE. CYLINDERS 18 X 24 INCHES. SERVICE WEIGHT OF ENGINE, 35 TONS

½-inch gas pipe, perforated at intervals with small holes and supported at the top and bottom by small brackets fixed to the tender. All that it is necessary to do to discover the height of water in the tender is to turn the handle (which is formed by bending the tube over at the top) in the direction shown in the cut. This opens a cock at the base of the column and allows the water from the tender to enter the tube; then by noting the topmost hole at which the water escapes one knows the approximate height at which the water is standing within the tank. Three of these devices can be provided at about the cost of one of the regular gauge-glasses and fittings.

The most exhaustive description of the Crewe Works would, indeed, be incomplete unless it contained special reference to the man who has been mainly instrumental in making the place what it is at the present time,—not only the largest, but the most complete and adequately equipped establishment of its kind in the world. Entering the service of the company in 1851, it was, as has been already stated, in 1871 that Mr. Webb was appointed Locomotive Superintendent (a title since changed to that of Chief Mechanical Superintendent) of the London & North-Western Railway, and he immediately set about the great task of developing the works and bringing it to its present remarkable state of progressive efficiency. To this task he devoted the greater part of his time and energies during the whole of the thirty-two intervening years.

When he took up the reins of government at Crewe he followed in worthy footsteps, for John Ramsbottom was a leading light in his profession and proved himself to be an able organiser and a capable director of the locomotive policy of the greatest of English railways. It rested with Mr. Webb, however, to carry out, with amplifications, the greater part of the ultimate aims which his predecessor had in view, the accomplishment of which has made Crewe famous wherever railways and locomotives are to be found.

Mr. Webb's name is most prominently connected in the minds of the majority with the efforts he has made during the last twenty-one years in the cause of locomotive compounding. But for Mr. Webb the part which British engineers have played in the development of this branch of locomotive prac-

tice would have been insignificant. He it is who, in the face of the overwhelming tide of opinion existing in Great Britain against it, stood out, alone and single-handed, the avowed champion of the compound principle, and the splendid results achieved by his engines form the best answer to those critics who, for one reason or another, never lost an opportunity of advertising their professed opposition to those methods which Mr. Webb so long and energetically upheld.

As is well known, foreign engineering opinion is strongly and increasingly in favour of compounding, and it is fast becoming the rule, and not the exception, upon the Continent to find the best and most important locomotive service entrusted to compound engines. The Northern Railway of France is pre-eminent in this respect, and the large four-cylinder, ten-wheeled locomotives of modern design which are there used are exceedingly powerful machines, and have become celebrated for the excellence of the work which they perform.

Comparisons are sometimes made between these engines and those of Mr. Webb's design, but the conditions under which the two types work differ so largely from each other and the circumstances are so markedly dissimilar that it is impossible to draw any really valuable conclusions or arrive, by logical methods, at any definite opinion as to the relative merits of the two designs, such as would be possible if they were both employed in the work of hauling identical loads over the same section of the same railway system.

The writer, after a somewhat lengthy experience of Mr. Webb's engines,—particularly those of the "Alfred the Great" type of four-cylinder compounds,—frequently, under privileged circumstances, firmly believes that, given identical conditions, of wind, weather, loads and gradients, it is tolerably certain that the English engines would be able to equal the best performances of their French contemporaries. Such speeds as 60 miles an hour and upwards, with which the latter are credited in everyday working, would be impracticable on such an extremely busy system as the London & North-Western Railway and would lead to a great amount of inconvenience and delay in dealing with other and slower traffic.

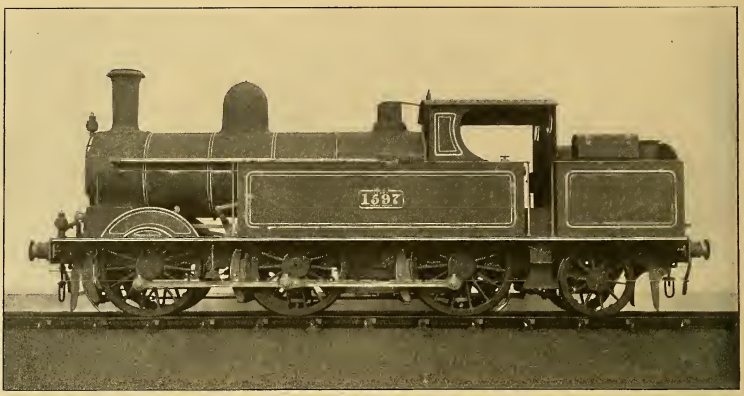
It is a fact that the London & North-Western Railway compounds are, taken all round, the hardest worked of any locomotives in Great Britain. Not only are they called upon to deal with loads of exceptional weight at high average speeds, but they are worked on the principle of obtaining as great a mileage as is possible within a given period of time; therefore, their "off duty" spells are never of very long duration.

The running of the new "two-hour" trains between Birmingham and London, a distance of 113 miles, necessitates locomotive work of the very highest character, and the many other heavily-weighted and closely-timed expresses make the use of engines of undoubted efficiency absolutely necessary in order that punctuality may be observed.

The 5.30 P. M. dining car express, which covers the distance of 158 miles between London (Euston) and Crewe, without any intermediate stop, in 2 hours and 55 minutes (equal to about 53½ miles an hour), affords one of the finest examples of sustained effort on the part of a locomotive to be found on any British railway, especially when the weight of the train, which averages 394 tons exclusive of engine and tender, is taken into consideration.

It must not be inferred that Mr. Webb's achievements in locomotive designing prevented him from giving attention to the many other kinds of mechanism which are required upon a railway in addition to locomotives. He is the patentee of upwards of seventy inventions, covering a wide range of subjects.

As has already been stated, Mr. Webb entered Crewe Works in 1851, eight years after they were established, as a pupil of the late Mr. Francis Trevithick, the first locomotive superintendent at Crewe. He was appointed chief draughtsman in 1859 and works manager two years later, a position which he held for five years, resigning it to become manager of the Bolton Iron &



A SIX COUPLED PASSENGER TANK ENGINE WITH SIXTY-INCH DRIVING WHEELS AND 18 X 24-INCH CYLINDERS. TOTAL SERVICE WEIGHT, 52 TONS

Steel Company's works. Five years later he returned to the London & North-Western Railway as locomotive superintendent and chief mechanical engineer,—a position which he has occupied for thirty-two consecutive years. He has been Mayor of Crewe twice, and in recognition of his services to the town, the freedom of the borough was conferred upon him in 1900. It was through Mr. Webb's initiative that the Crewe Volunteer Engineer Corps came into existence, and which, during the late South African war, sent over 280 skilled men to be attached to the Royal Engineers. These men did splendid work in maintaining railway communication and working the steam transport. He is at the present time vice-president of the Institution of Civil Engineers. He is also president of the Crewe Mechanics' Institution, in which establishment he takes the liveliest and most direct interest and towards the development of which he has done more than anyone else.

As is now generally known, Mr. Webb retired on July 1, 1903, from his position as Chief Mechanical Superintendent of the London & North-Western Railway, and the engineering world in general, and British locomotive engineering in particular, have thus lost, so far as active service is concerned, one of its most useful and distinguished members.

The growth of the town of Crewe has been commensurate with that of the works. At the present time the population numbers about 42,000 persons, consisting almost entirely of the company's employees, their families, and the tradesmen who supply them. The railway company have built and are the owners of no fewer than 845 workmen's cottages, and, in addition to this, a considerable number have been added by the workmen themselves. As the town is almost entirely dependent upon the railway company, the directors have aided, by their countenance and material support, in nearly every public movement deserving of their liberality. They have erected public baths; built and keep in repair large and commodious schools in various parts of the town; and they also supply the gas and water.

A technical college, known as the Crewe Mechanics' Institution, has been provided, and is liberally supported by the company. This institution comprises a library of over 10,000 volumes, many of which are works on scientific subjects; comfortable reading rooms, liberally supplied with newspapers, magazines and periodicals; class rooms,

smoking room, gymnasium, specification room, and a lecture hall capable of accommodating upwards of 800 persons. Evening classes are regularly held in the winter months for instruction in commercial subjects and in art, science and technology, and these classes are largely attended by those employed in the works during the day. A mechanics' shop has been added to the institution for the use of the members, and this is fitted up with lathes, drilling and shaping machines, smiths' hearths, and other requisites. In 1893 the average membership was 1,250 persons,—a fact which demonstrates very clearly the value which is placed upon the facilities afforded.

A savings bank has been instituted by the railway company to encourage habits of prudence and economy among their employees and their families; interest at the rate of 3½ per cent. per annum is paid by the company on all sums deposited. The directors presented a public park to the town in 1888 as a memorial of her late Majesty Queen Victoria's Jubilee. The ornamental grounds, which cover about forty acres, were opened by the Duke of Cambridge on June 9 of the year referred to.

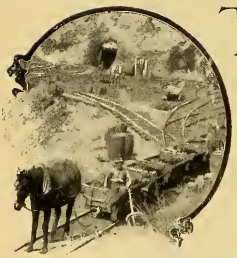
In conclusion, the author takes the opportunity afforded of cordially thanking Mr. Webb for his great kindness in providing all the necessary facilities for viewing the works, for his liberality in supplying photographs (some of which were taken specially for the purposes of this article), and for granting access to sources of information but for which it would have been quite impossible to deal with the subject in any degree of adequacy; and further, the author's best thanks are extended to Mr. J. N. Jackson, the genial Chief of the Drawing Office Department at Crewe, who,—at Mr. Webb's request,—interested himself in the preparation of the article and afforded assistance not only by offering many valuable suggestions, but by active co-operation with regard to the reviewing and adjusting of the many matters of detail which had to be taken into consideration.

WEBB'S WATER GAUGE FOR ENGINE TENDERS. THIS VIEW SHOWS POSITION OF TUBES AND HOLES WHEN THE COCK AT THE BOTTOM OF THE TANK IS OPEN. THE WATER RISES IN THE TUBE TO THE LEVEL OF THE WATER IN THE TANK AND ESCAPES THROUGH THE SMALL HOLES, THUS INDICATING APPROXIMATELY THE HEIGHT OF WATER

INCREASING THE COKE YIELD FROM BEE-HIVE OVENS

WASTES IN AMERICAN PRACTICE

By Charles Catlett



THE writer's attention was called several years ago to the possibility of increasing the yield of coke per ton of coal, as obtained in certain bee-hive ovens. Since then he has had occasion to witness the indifference with which this matter is ordinarily considered, and, on the other hand, the marked improvement which comes from even a most perfunctory effort in that direction; and he is almost tempted to say that nothing in connection with the coking of coal is at present so important. There are other factors which are fundamental and necessary; but they have been considered already; while the question of yield is, as a rule, absolutely ignored, or some figure is taken as the result of a special burning of one or two ovens, and the assumption is made that the whole battery is yielding at that rate. The uncertainty of this assumption may be illustrated by saying that the burning of a single oven in a battery frequently gives, by actual weight, as much as 69 or 70 per cent. of merchantable coke, while the battery as a whole is yielding only an average of 63 per cent.

From a paper on the subject presented by the writer at one of the recent meetings of the American Institute of Mining Engineers, it has been thought of further interest, therefore, to reproduce here the following:—Only from careful records, checked at least once a month, of the weight of the coal going to the ovens and the weight of coke produced, can any correct idea of the actual yield be gained, or methods be modified so as to produce good results; yet, as a rule, the crudest estimates are usually the only available data. In may cases there are reasons for this loose practice. The coal is mined by measurement; the payment for drawing the ovens is in proportion to the amount of coal which goes to them; and, not uncommonly, the royalty is so much a ton of coke, not of coal. The mine manager is tempted to increase the volume of coal mined which is paid for as a ton, and to do the same thing in charging the ovens. Nor does he wish the royalty charge to be changed in any way. The result is that often his records do not truly show within quite a large percentage the actual weight of coal mined and charged in his ovens. Yet until he has accurate information on this point he cannot tell what is the amount of loss under present methods, or how to improve on them. I venture the assertion that the owners of many plants in the Connellsville region, in Pennsylvania, otherwise well managed, who complacently accept the statement that the yield of the Connellsville coal in coke is 66 per cent., would be astonished should they ascertain what is their actual yield.

The effect of a slight increase in the yield per cent. is greater than is usually realised. For instance, if a battery of ovens is yielding 60 per cent., and the yield is increased to 61 per cent., there has been an absolute saving of one-sixtieth, or 1.66 per cent., of the total value of the coke formerly produced, less the cost of loading,—since all the

BEE-HIVE OVENS IN COURSE OF ERECTION

other expenses remain the same. The writer has never yet examined a battery of ovens, where the attention of the management had not been called to the yield, in which it was not possible to make an increase of from 3 to 5 per cent. If, for purposes of illustration, we assume that the former yield was 60 per cent. (which figure does not vary greatly from the general practice), the saving of 3 per cent. would mean a total saving of one-twentieth of the output, and a saving of 5 per cent. would mean a total saving of one-twelfth of the output. Enormous as this difference may seem, it is exceedingly common, and at times is greatly exceeded. The writer knows of a coking district which, as a whole, is yielding only 55 or 56 per cent., though the coal could readily be made to yield from 65 to 70 per cent.

The loss of the by-products in the 63,000 bee-hive coke ovens in the United States is an appalling waste of natural supplies, and has been a fruitful source of discussion as to the wastefulness of American methods. If, however, I am right in my belief that my own experience fairly represents the conditions at the majority of the ovens in operation, there are at least 1,000,000 to 2,000,000 tons of coke annually consumed and lost in American bee-hive ovens which, by anything like reasonable care and attention, could be saved.

This waste is worse than useless. The excess of heat available from the gases, as shown by tests of a great variety of coals in the retort ovens and ordinary tests of single bee-hive ovens, demonstrates that there is not a good coking-coal which could not be coked in bee-hive ovens by the heat derived from the combustion of its gases alone, and that the burning up of any coke which has already been formed is, therefore, a positive, unnecessary loss.

But more than that,—the burning of a portion of the coke necessarily results in the deposition of ash on the remainder. This retards the transmission of heat from the hottest portion of the oven (just above the coke) to the unburnt portion of the coke toward the bottom of the oven; and, moreover, when the oven is watered down, this ash

is washed through the pores of the coke and retained there, thus increasing the ash beyond its normal and proper proportion. A careful examination will disclose this ash in the pores of the coke. I have known cases, where the coal was naturally high in ash (and, therefore, the ash-content was a matter of the greatest importance), in which enough coke was consumed to add 4 per cent. of ash to the entire product. In nearly all cases the increase of ash due to the burning of coke is conspicuous.

The theoretical yield of the coke can be determined within a fair degree of exactness from the proximate analysis of the coal. The coke carries all the ash and fixed carbon, and, even under the best work, a certain portion of volatile matter and moisture. The sulphur will probably be distributed in the coke, as indicated in the analysis. In other words, a coal of the following composition,—moisture, 1.25; volatile matter, 26.30; fixed carbon, 66.05; and ash, 6.40; total, 100,—may be expected to give a theoretical yield of 66.05 + 6.40 = 72.45 per cent. of coke. To this should be added at least 1 per cent. for the moisture and volatile matter, which are retained by average "good coke," so that the theoretical yield of coke made from the above coal can be assumed to be 73.45 per cent. Dividing the fixed carbon, ash and 1 per cent. of moisture and volatile matter by that figure, we would get, for the coke made from this coal:—Fixed carbon, 89.92; ash, 8.71; volatile matter and moisture, 1.36; total, 99.99.

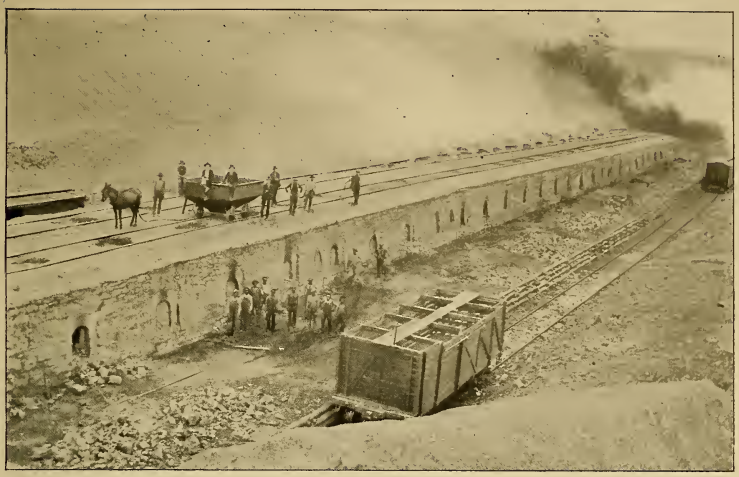
In carefully-burned ovens the ash should not be increased or the carbon reduced by more than 0.5 per cent. from the figures obtained by calculations like the above, and the volatile matter and moisture may both be reduced from the above figures, though they are often greater. There are various modifying factors, the exact measure of which cannot be accurately determined. Among these is the deposit of carbon from decomposition of the gases. The amount of ash is inversely proportional to the yield, so that increase in the yield at the same time decreases the ash. It is not uncommon to claim an advantage from an increase in a coke, up to a certain point, of ash of suitable composition, as a means of hardening the structure; but no one will claim any advantage from the ash which does not form part of the structure, but is simply derived from outside sources, either by collection or otherwise. This latter ash is simply paid for as coke, and then must be got rid of. It must not be confounded with that which enters into the structure.

After the coal goes to the ovens there are several ways in which the ash in the coke produced may be increased above the theoretical amount. A portion may be derived from the dirt-filling around the trunnel-head; a portion from forking the coke from a dirty yard; a small amount from impure water used in quenching; but by far the largest amount comes from the ashes of the coke burnt up in the oven. As the latter is almost in reverse proportion to the yield, it is obvious that the advantage of yield is not confined entirely to the saving of coke, but goes hand in hand with improved quality.

The "commercial" yield will be determined by local conditions and the character of the particular coal. It is the theoretical yield, less the losses in burning and of fine coke in handling, and increased by the ashes and dirt gathered, as noted above.

In good coking-coals, high in volatile matter, the "breeze," or fine coke, will run 2 or 3 per cent., and the commercial yield should not be more than from 3 to 5 per cent. below the theoretical. It is possible to do better, but anything not so good may be considered bad practice. With higher fixed carbon in the coal, and particularly when the coal is low in ash, and will burn or "cut" readily by small leaks admitting air, the difference between the theoretical and the commercial yield may be between 5 and 10 per cent.; but first-class work should approximate the former figure.

The question of yield is involved to a greater or less extent in all the operations connected with handling the coke ovens. The conditions which permit of



THE OLD WAY OF CHARGING OVENS BY MULE-POWER

the greatest regularity of drawing and charging, in which the leveling is done as it should be, the ovens are watered down to the best advantage, and are worked to their capacity, etc., are all factors affecting the yield. A plant in which the discipline and management are good will naturally have a better yield than where the management is lax; but after all this is said there still remains the difference due peculiarly to a special effort, or want of effort, in the way of handling the draught and the oven with special reference to this point.

The principal thing which affects the question of yield is the care and skill with which the draughting, or admission and exclusion of air to the oven, is controlled.

The object and purpose of the draughting is to secure a satisfactory degree of heat at the right time, and as nearly as possible to secure this heat from the gases which are driven off during the process of coking, and which would otherwise be entirely wasted. The more nearly it is possible to completely burn out the coke at a satisfactory temperature and leave the ovens in first-class condition for the next charge, without burning any of the coke which has been formed, the more nearly do we attain perfect results.

The mistake is commonly made of assuming that at all stages of the process, whatever may be the condition of the oven, an increase of draught means an increase of temperature, and a decrease of draught, a decrease of temperature. The most casual examination will show that this is not the case. At the first stage of the burning, before the gases which will add to the heat by their combustion have commenced to come off, it is possible to cool the oven by excessive draught; and it is common and advisable practice to cover the ovens immediately after drawing, and re-cover them after charging, with a view to their "catching-up" more rapidly. By this means the heat stored in the walls finds its way to the inside of the oven.

There is apt to be a time, within the first twelve hours after an oven has "caught up," when the amount of gas formed is in excess of the ability of anything like an ordinary draught-orifice to furnish the necessary air to retain the oven at a temperature for perfect combustion. During this time, also, the

trunnel-head of ordinary size has great difficulty in disposing of the products of combustion. Later in the process this condition is reversed, and the amount of air is apt to be in excess of what is necessary to burn the gases which are coming off; and, finally, if the draught is not changed, it becomes greatly in excess of the requirements of the ovens. From this stage to the end of the burning it is thoroughly possible for an oven to continue to cool, even with the admission of a large volume of air. In other words, the heat furnished by the small amount of gas which is coming off, and from the consumption of a portion of the coke, is less than the lowering of temperature caused by the loss of heat from the trunnel-head and from radiation; and this difference is increased by increasing the draught.

The attempt to hurry an oven which has been allowed to cool, and which is continuing to cool, while exhibiting a number of "candles," by giving to it an excess of draught, is often indulged in; but it will be found very much better to endeavour to burn the oven so as to keep the heat up to a maximum towards the end of the blast, at the time when it is needed most to reach the coal at the bottom of the oven, rather than to try to replace the heat by an effort to burn a portion of the coke. This effort is always disappointing in results. As a general proposition, in nine times out of ten the draughting is too heavy, and the oven can be brought out in better shape by a more uniform draughting extending over a longer period. As a rule, from 20 to 25 square inches, in the form of a circular draught at the top of the door, which may be as much as 40 inches high, will be ample for the largest oven which it may be desirous to burn out, while this should be reduced by at least one, or possibly two changes, as the oven is burnt out, so that the amount of air shall at no time be greatly in excess of what is necessary to completely and clearly burn off the escaping gas.

HERE THE CHARGING LARRIES ARE OPERATED BY THE OVERHEAD ELECTRIC TROLLEY SYSTEM

As a rule, the tendency is to make the trunnel-heads too large. Of course, they have to be large enough to take with sufficient promptness the coal from the larries; but the standard forms of larry will readily discharge into an open-

COKE-OVENS—MONTHLY EFFICIENCY RECORD—COKE-OVENS

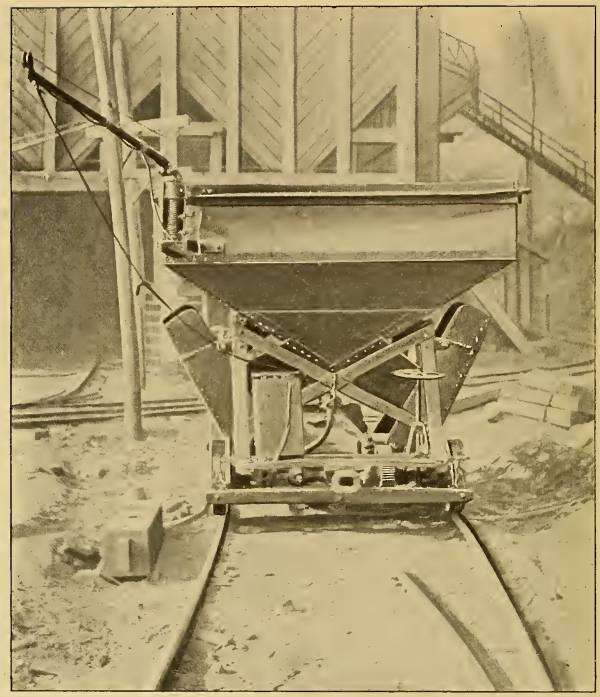
1902	Tons Coke Made	Tons Coal Used	Yield in Per Cent. Coal Used			Number of Ovens Drawn			Coal Charged per Oven			1902	
			Theoretical	Practical	Actual	Efficiency Per Cent.	Possible	Actual	Efficiency Per Cent.	Possible Tons	Actual Tons	Efficiency Per Cent.	Monthly Efficiency Record	Remarks
			Per Ct.	P. Ct.	Per Ct.	Per Ct.			Per Ct.			Per Ct.	Per Ct.	
January	8 911.65	13,957.00	76.95	67	63.85	95.30	3,405	2,925	85.93	5.25	4.77	90.85	74.39	More 48-hour coke was made than 72-hour coke
February	8,565.10	13,215.70	77.59	67	64.81	96.73	2,995	2,885	99.66	5.25	4.42	84.19	81.15	
March	9,107.05	14,251.80	77.38	67	63.90	95.37	3,575	2,888	80.78	5.25	4.93	93.90	72.33	The loss was in burning the coke overtime
April	8,853.20	14,403.55	77.30	67	61.46	91.73	3,416	2,910	85.18	5.25	4.95	94.28	73.67	
May	9,341.65	14,821.6	74.7	67	63.02	94.06	3,455	3,032	87.75	5.25	4.88	92.95	76.72	The loss was in small charges.
June	6,977.85	10,803.8	77.1	67	64.58	96.38	3,457	2,869	87.96	5.25	4.18	79.61	67.49	The charges for the ovens are too small
July	5,506.45	8,448.4	75.0	67	65.20	97.31	1,812	1,644	90.72	5.25	5.33	101.52	89.62	All adjustments in the coke manufacturing increased in efficiency, hence the good result

ing 12 inches in diameter, and the writer has never yet seen an oven or a coal which would not give better results with an orifice of that size than with a larger one. Yet larger sizes are common. The writer knows of one manufacturer whose standard size is 16 inches, or nearly twice the area of a 12-inch trunnel-head. The latter is abundantly able to carry off, under the best conditions of draughting, the products of combustion; and any excess above this very materially increases the loss of heat and interferes with the efficiency of the oven.

The small-sized opening may be slightly inadequate at the beginning of the blast; but as the gases come off in smaller quantity and more slowly, it is invaluable in retaining the heat so much needed at the later stage. The smallest trunnel-head the writer has tried for a 12-foot oven was 11 inches in diameter, and the results were fairly good. The ordinary difficulties connected with prompt charging limit the size to 12 inches and upward, and the smallest size that can be readily handled by the charging facilities will be found the best.

The use of lids is extremely desirable. Properly handled, they mean a great deal as regards the matter of yield. The retention of heat in the oven is, of course, of the utmost importance. The ovens should be covered as soon as drawn. They should be covered when charged until they are "caught up"; and as soon as the oven is practically burnt out, the draught should be cut off entirely, and the trunnel-head partially or entirely closed. This will aid in keeping the ovens in the best possible condition, and will prevent the burning up of a large amount of coke. Particularly should the doors and jambs be kept tight, and the smallest cracks stopped. The consumption of coke from neglect of this is enormously larger than would be supposed at first sight.

It is almost impossible to make any improvement in the matter of yield without keeping records in such shape as to show what are the good or bad results of any method of treatment. It is absolutely necessary, therefore, that arrangements be made to calculate, from either



AN ELECTRICALLY-DRIVEN LARRY FOR CHARGING COKE OVENS

the railroad or the larry-weights, to within at least 0.25 per cent. of the actual yield, within one or two days from the end of each month. With this, there is the strongest incentive to try to improve; and without it, there is the strongest reason for making no change, since it cannot be known whether a change is advantageous or not.

It is impossible to give a form for such a record, because it will vary with each plant; but attention may be called to the fact that that portion of the coke and coal on the yard or in bins, or in transit at the beginning and end of each month, if carefully estimated, cannot introduce a large error; and any such error which is made one month is balanced in the succeeding months; so that, if actual weights be taken of the coal that goes to the ovens and the coke that is shipped away in each month, the other amounts being estimated, the results will be very close.

The form on the opposite page is given as a valuable one for keeping the monthly record and comparing the work month by month. It is a copy of a report from a plant in actual operation. The monthly efficiency record will be found by multiplying the efficiency per cent. of yield, the efficiency per cent. of coal, and the efficiency per cent. of the number of ovens drawn, and will no doubt astonish some coke-makers when they apply this form to their own operations. The theoretical yield is determined as

explained, and the practical yield is is something smaller, depending on the tendency to make fine materials or "breeze," the composition of the coal, the condition of the ovens and equipment, etc.

As promptness and regularity in all the steps of coke manufacture are essential for high yield, the following form of daily report will be found of service in locating promptly weak points in the work. It should be transferred to a scratcher in the office in such form that the percentage for each day follows that of the previous day in a vertical column, and changes can be noticed at a glance.

COKE DEPARTMENT—DAILY EFFICIENCY RECORD

Draughting:	Required	Actual	Efficiency Record Per Cent
Ovens burnt out on time	A	B	
Ovens ready to draw	C	D	
Ovens standing over	E	F	
Drawing:			
Number of ovens	G	H	
Promptness (hours)	I	J	
Coal supply:			
Number of larries	K	L	
Charging:			
Number of larries	M	N	
Promptness (hours)	O	P	
Loading coke:			
Cars furnished	Q	R	
Cars loaded	S	T	
Loaders	U	V	

See note below

A. The number of ovens charged to come out to-day.

B. The number of ovens charged to come out to-day which came out in the proper time.

C. The ovens charged to come out to-day and those brought over from previous days.

D. All ovens ready to pull at the proper time.

E Is always zero.

F. The ovens ready to pull at the proper time which were not pulled.

G. All ovens ready to pull at the proper hour. The number is the same as D.

H Number of ovens pulled.

I. Number of hours from the time the first oven is started until the last is finished.

K. The number of larries of coal needed to supply the ovens that should have been drawn that day. L, the number available.

M. The number of larries of coal needed to charge the ovens drawn that day.

O. The number is the same as I. The larries used in charging start later, but should take the same number of hours as those used in drawing.

Q. The number of cars asked for from the railroad company. It is seldom less, and is often more than the number required for one day's output of coke.

R. The number of cars furnished.

S. The number of cars to be loaded—evidently the same number as R.

U. Is the number of loaders required to load R.

V. The actual number of loaders.

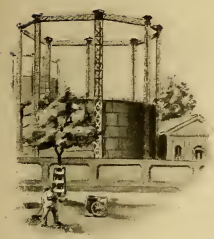
A PORTION OF THE LEWISBURG, ALABAMA, PLANT OF THE ALABAMA CONSOLIDATED COAL AND IRON COMPANY. A SIMPLE WAY IS HERE SHOWN OF SAVING A PART OF ONE OF THE BY-PRODUCTS FROM BEE-HIVE OVENS. THE BOILER ON TOP UTILISES THE WASTE HEAT FROM TEN OVENS AND, WITHOUT AFFECTINC THE COKE-MAKING, LEADS TO A SAVING OF ABOUT 300 TONS OF COAL A MONTH, FORMERLY NEEDED TO RAISE STEAM

The "efficiency record per cent." may be illustrated as follows:—Suppose A is 100 and B 75; then the efficiency record of "ovens burnt out on time" is 75. If 25 ovens were left over from the previous day, the full number which should have been ready to draw to-day (C) would be $100 + 25 = 125$; but as 25 ovens were not burnt out, D is only 100, and the record per cent. of "ovens ready to draw" is 80. "Ovens standing over" may be due to defective draughting, failure to draw, or other causes. As E is always zero, it is not practicable to represent the ratio between E and F by percentage. Under "drawing," G to-day is 100, and if only 65 (H) are drawn, the percentage efficiency on this line would be 65. If I should be 8 hours and J is 10 hours, the efficiency record per cent. for "promptness" would be only 80. The coal supply should always be enough for the regular number of ovens due each morning, or 100 (K); but if there is only coal enough for 90 (L), the efficiency record per cent. of coal supply would be only 90. The total amount of coal actually needed on any day might be more or less than the normal. To-day M would be only 65, and if N is 65, the charging "efficiency record per cent." is 100. O should in this case be 8, and if P were 12, the "efficiency record per cent." of promptness in charging would be only 66.66. If Q is 10, and R is 5, the car supply for the day is only 50 per cent. of what it should be, and if S is 5 and T is 3, then the loading of cars furnished is only 60 per cent. of what it should be. U and V simply enable the superintendent to know whether the failure in loading is due to want of men or from some other cause. The efficiency for the day is in the following order:—Car supply, 50; loading cars, 60; drawing, 65; promptness in charging, 66.66; ovens burnt out on time, 75; promptness in drawing, 80; normal coal supply, 90; charging, 100. The weakest points in the actual operation of the ovens are "drawing" and "ovens burnt out"; and the normal coal supply should also be looked after. As the coke boss is usually not strong at figures, the report should be turned in, and the percentage calculated at the office.

GAS FOR HOUSE HEATING

CONDITIONS UNDER WHICH IT MAY BE USED TO BEST ADVANTAGE

By Walton Forstall, Assistant Engineer of Distribution for the United Gas Improvement Company



DURING the time of the Pennsylvania coal strike last year thousands of householders in different parts of the United States shut down coal stoves and started gas ranges, and thousands more bought gas ranges as soon as their coal was used up or when they realised the wisdom of husbanding that kind of fuel. For such the coal strike had no terrors, and their number may be judged from the fact that in one large city alone 90,000 families,—almost one out of every two on the line of the gas mains,—were cooking with gas long before winter set in, this representing a gain of nearly 40,000 gas stoves since the strike began. In several of the large cities, judging by the increased sales of gas, the increase in stoves must have been very large also.

With the approach of cold weather those who were unable to pay the price asked for coal, or to procure it at any price, turned to gas and oil for heating, and the supplies of oil and gas heaters were soon exhausted. Had the coal strike continued one month longer, gas would have meant to thousands their only salvation from starvation and cold, and the tremendous demand for gas might have exceeded the manufacturing capacity available, as an increase of 100 per cent. over last year was not unlikely.

In view of the increasing interest thus shown in the use of gas for heating, and considering also the general ignorance as to its cost compared with coal, and the conditions under which it may be used to best advantage, the following particulars may be of value.

Considering first the question of relative cost, the heating value of artificial gas is from 650 to 700 British thermal units per cubic foot. Using the higher figure for the sake of simplicity, this means that each cubic foot, if burned under theoretical conditions, will raise the temperature of 700 pounds of water 1° F. One thousand cubic feet, therefore, contain 700,000 heat units. Each pound of hard coal contains 12,500 heat units, and a net ton thus contains 25,000,000. Therefore, if all the heat contained in both kinds of fuel could be made effective in practice, 1000 cubic feet of gas would be worth in heat value only about 3 per cent. of a ton of coal, or, to express it in another way, 36,000 cubic feet of gas would be required to replace a ton.

Comparing the use of gas in flueless heaters with that of coal in a heating stove, 100 per cent. efficiency may be allowed for the gas and not more than 70 per cent. for the coal. If the coal is used in a hot-air furnace, not more than 50 per cent. of its heat is utilised. Therefore, in the first case 25,000, and in the second 18,000, cubic feet of gas will replace one ton of coal. It is apparent from these figures that even if questions of health did not prevent continuous use of flueless heaters, such use would be prohibited by the excessive expense. This expense is increased when gas is used with a flue connection, as only 70 per cent. of its heat is then realised under the best conditions.

However, because of the saving through using gas only at the time

when it is actually needed, experience has shown that when gas is used in place of coal in a hot air furnace, the results throughout several winters indicate that from twenty to twenty-four thou-

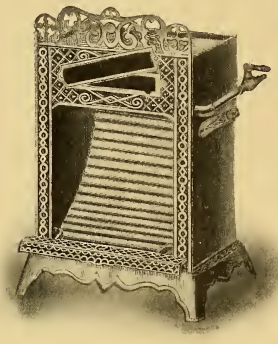


FIG. 1.—THE REFLECTOR TYPE OF HEATER

sand cubic feet of gas will replace a ton of coal. Therefore, if gas is taken at a dollar per thousand cubic feet and coal at six dollars per net ton, the cost of gas heating would not be more than four times that of coal, and when the latter involves an expense for attendance, the ratio may not be as high as three to one. It is still high enough to make gas out of the question for the great majority, for anything like continuous heating.

The conditions under which it may be used to advantage, as regards both economy and convenience, are in rooms with no other source of heat, and in which warmth in the coldest weather is required for only a few hours per day; or universally through a building during those days in early autumn or late spring when the room temperatures are in the fifties, and the necessary ten or more degrees of heat may be obtained by slight and intermittent use of gas. Such conditions of intermittent use are precisely similar to those ruling where gas is used for cooking, for which purpose dollar gas has been found cheaper than six-dollar coal.

The beginnings of gas heaters date back twenty years, to the era of two-dollar gas, and for a long time the manufacturers of such heaters were unaided in their fight for a market, as the gas companies seemed unable to realise the business possibilities involved. However, there was a steady demand for heaters from natural gas areas, and this maintained the industry pending the education of gas companies and the public in the use of artificial gas as a source of heat.

The development of the heaters may be best studied by dividing them into three classes,—those which are generally movable and have, or have not, provision for conveying the products of combustion into a flue; those which are fixed in one room; and those fixed in cellars, by which an entire building is heated. The last two classes always have flue connections.

The reflector type of heater shown in Fig. 1 was one of the earliest of the first

FIG. 2.—A CYLINDRICAL HEATER

class. A cheerful glow was obtained with this, though at the expense of economy, since with the flame at the top of the heater the products of com-

bustion went into the air before heating much of the metal, and the heater thus failed as a radiator.

Following the reflector, came the cylindrical heater, shown in Fig. 2. Illuminating flames here burned at the bottom, and by more or less restricting the exit of the products of combustion, a fair amount of radiation was secured. After some years of experience, however, it was found that the multiple-tube form, shown in Fig. 3, was the most efficient in radiation. This type is known as a "radiator," and varies as to the number and height of tubes, according to the quantity of heat needed, or according to the ideas of the manufacturer. The longer the tubes, the more the heat from the gas is kept in the lower part of the room. It is usual to burn but two flames in each tube, each flame consuming about 3 cubic feet per hour. Occasionally baffle plates are introduced to retard the upward progress of the heated air. It has also been found that when either radiators or cylindrical heaters are perforated (see Fig. 4), a still larger amount of the heat is retained in the lower levels of the room.

The field of use for heaters of the first class is a very wide one, covering all cases where a quickly movable source of rapid heating is desired. By means of "independent cocks" (a form of cock allowing a heating and lighting attachment to the same outlet) and rubber tubing, any gas consumer has a more convenient and a safer heating agent in a gas radiator than is afforded by an oil heater. There are certain limitations, however, which it is wiser to recognise than to attempt to ignore. The mobility afforded by the tubing, involves possibility of accident at the junction of tubing and pipe if the former is not properly put on; but no accident will ever occur if this possibility be kept in mind and proper care be always exercised.

The other requisite to mobility,—the absence of a flue,—prevents any long-continued use of the heater because of the vitiation of the atmosphere. This is a point on which there is much public ignorance, and thousands of flueless heaters have been bought with the idea that, except for the cost, they would furnish as satisfactory a source of heat as the coal furnace. Happily, however, no households have had to discover by actual experience how little fit for respiration the air of their rooms would have been after these heaters had been burning in them all day. Whenever a heater is to be used in one room only, it should have an iron pipe connection, and if the use must be long continued, a type suitable for flue connection, of the kind shown in Fig. 5, should be purchased.

In addition to carbonic acid, the combustion of gas produces water vapour,

FIG. 3.—A GAS RADIATOR

and this, in time, adds to bodily discomfort. Recently forms of "condensing stoves" have been designed,—radiators that condense this water vapour, and thus make effective the latent heat of vapourisation.

The gas consumption in heaters of the first class, varies from 12 to 50 cubic feet per hour. It is fair to say that for every 1600 square feet of wall surface 1 cubic foot of gas per hour will be required for every degree Fahrenheit in the difference between the temperature maintained in the room and that of the outside air. In a room $10' \times 12' \times 9'$

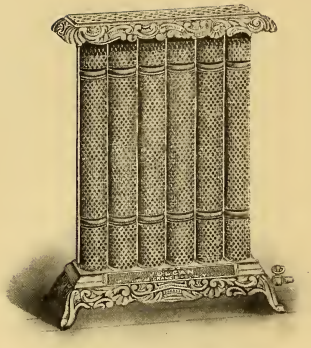


FIG. 4.—A GAS RADIATOR WITH PERFORATED TUBES

high, with an inside temperature of 70° and an outside one of 40°, this would require a steady consumption of 7 cubic feet per hour. In practice, probably a four-tube radiator, consuming 24 feet per hour, would be used, thus raising the temperature quickly, allowing the radiator either to be shut off entirely or turned down low.

The second class of heaters, those designed for permanent use in one room only, are the various types of gas "fires,"—fronts (Fig. 5), logs (Fig. 6), and grates (Fig. 8). Their gas consumption varies from 30 to 100 cubic feet per hour. With the occasional exception of those varieties of gas fronts of small consumption, they always have a flue connection. This disposal of combustion products up a chimney makes these "fires" more expensive than the flueless heater, but the opportunities for room heating by gas, under the conditions previously defined as favourable, are numerous enough to warrant every householder in installing one or two "fires." Their extra consumption, as compared with a flueless heater, is outweighed by their greater convenience, healthfulness and safety. The movable heater is, at best, a makeshift, and its use may be largely avoided by proper house design.

There is a difference between the heaters of the second and third classes and those of the first class in the method of burning the gas, and the reason for this difference involves an explanation of the phenomena of combustion as occurring in a luminous and in an atmospheric or blue flame. The former contains carbon particles heated to incandescence, and any contact of the flame with cooler surfaces results in setting free a quantity of carbon in the form of soot, of which part will stick to the surface and part go off as smoke. In an atmospheric flame, the air mixed

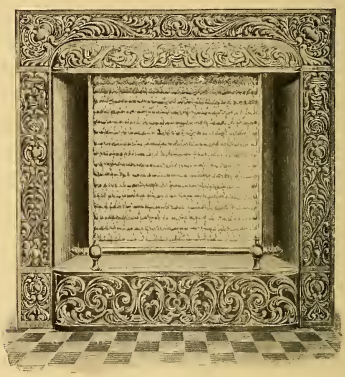


FIG. 5.—A GAS "FRONT"

FIG. 6.—GAS LOGS

with the gas previous to ignition, brings about the partial consumption of the hydrocarbons before they are sufficiently heated to be decomposed, and, therefore, reduces the number of particles in the flame to such an extent that no soot or smoke will result when the flame impinges on cool surfaces.

From what has been said it follows that, as in all types of gas fires the flames play against surfaces, the atmospheric burner must be used. In heaters and radiators there is no impinging of the flames, and so the luminous burner has been adopted in these as being simpler, more cheerful in appearance, capable of giving off more radiant heat, and not liable to lighting back, with its accompaniment of incomplete combustion.

There have been heaters of the first class with atmospheric burners, and it is quite within the bounds of possibility that some buyers thought a heater in which gas mixed with air was burnt, would prove more economical than one with the ordinary luminous flame. Of course, they were wrong. The quantity of heat produced by the perfect combustion of a cubic foot of gas is the same whether or not air is mixed with the gas previous to ignition. Also, as a direct consequence of this truth, the quantity of air required for combustion, and, therefore, the degree of vitiation of the atmosphere, is the same, no matter which form of burner is used. Wherever conditions will permit, the luminous burner is preferable.

Except, perhaps, that they give a better imitation of coal in the gas grates and of wood in the gas logs and possess more artistic design generally, the later types of gas "fires" show no development over the first styles. No gas "fire" may hope to possess the charms of a coal or wood fire, but on the score of readiness and cleanliness the gas appliance leaves nothing to be desired; in hackneyed phrase, "once tried, always used."

Coming to the third class, the only way in which artificial gas has been used to any extent for house heating from one source is in a hot air furnace (Fig. 7) made on lines similar to one for use

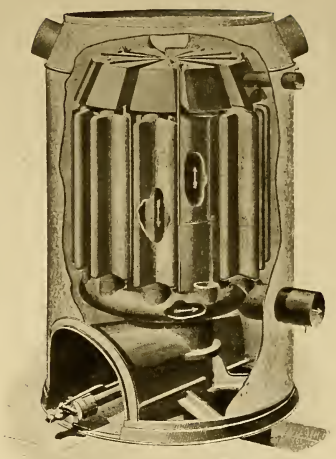


FIG. 7.—A HOT AIR FURNACE FOR HOUSE HEATING ADAPTED TO USE GAS AS FUEL

with coal, except in the construction of the combustion chamber which is made higher and narrower. On the score of convenience, a gas furnace may not be excelled by any coal-consuming device; a thermostat can be made to automatically maintain the temperature at any desired point, shutting off the gas supply as the temperature goes above and

FIG. 8.—A GAS GRATE

turning it on again as it goes below the standard. Thus, with such a furnace all the attention required is to light the pilot light on the first cold day in autumn and put it out when summer has come to stay. Between these two days the furnace will care for itself, and the house will always be just right, never too hot nor too cold. No cellar room need be provided for coal, and no dirt experienced from coal nor from ashes.

The cost of heating by such a furnace with dollar gas will be about four times the coal bill, but there are probably many people who would not hesitate to spend the extra money if they fully appreciated the cleanliness and convenience afforded by gas used in this way. The ratio of four to one just given is, as stated before, reduced to less than three to one where the use of coal involves a special charge for attendance.

The use of gas for heating purposes is destined to increase largely even at present prices, and this increase will be very rapid. Whether, however, gas will be generally used instead of coal as fuel in appliances for the continuous heating of dwellings, and whether such substitution may ever be made while coal remains anywhere near present prices, is a matter of considerable doubt.

THE PRESENT ATTITUDE OF ORGANISED LABOUR IN THE UNITED STATES

By Dr. R. W. Raymond

THE new thing in the labour situation is not the levy of blackmail by walking delegates, or the ruin of employers by boycott-conspiracy, or the persecution unto death of non-union workingmen. The new thing is the shocked surprise of so many good people at the discovery that such crimes universally accompany the campaigns of "labour," are frankly justified by its official representatives, and constitute its essential method and means. It is becoming impossible simply to excuse and deplore them as incidental attendants of a movement in itself praiseworthy.

Long ago I heard a leading officer of a league of labour unions declare, after stating the large number of their members, that these bodies existed only for the strike and the boycott. Since that time they have more than doubled their numbers, and perfected their tactics with much skill and boldness.

We must now face the fact that there is in the United States a vast organisation, "existing for the strike and the boycott." It is hardly worth while to discuss minor developments. Let us consider the national situation.

The American Federation of Labour, according to the statement of President Samuel Gompers, comprised a year ago more than 15,000 labour unions, of which about 14,000, in 91 national or international groups, were "affiliated," and the rest were directly chartered by the Federation. He claimed at that time that fifty new charters were issued daily, and that the membership was growing at the rate of 1,000,000 a year.

Mr. Gompers is the Pope of the Boycott. Little local boycotts are mere sputters of temporary spite, and, unless supported by him, may die out. But when Mr. Gompers launches the Major Excommunication "it means business"—or, more correctly, the destruction of business. A specimen of this industrial curse lies before me. It is addressed from the headquarters of the American Federation of Labour, Washington, D. C., "To All Affiliated Unions." It says that a certain manufacturing establishment "has been declared UNFAIR" (a capital crime), and ends thus:—

"Secretaries are requested to read this notice at union meetings, and labour and reform press please copy.

"Fraternally yours,
"SAMUEL GOMPERS.
"President A. F. of L."

Shrewd Mr. Gompers does not fire his heavy artillery too frequently, but in a case worthy of his attention there is no denying that it does terrible work. The proclamation of a reward for catching an escaped murderer may arouse a few hundred amateur, as well as professional, detectives; but one of these fraternal letters sets in motion 15,000 unions. Their own members are forbidden to use the goods of the house thus denounced, or of its customers. Every union man who defies this order is fined; and if he will not pay the fine or repeats the offence, he is expelled, and becomes a "scab," whom his employer must discharge on penalty of strike and boycott for himself.

But this is only the beginning. Local union committees wait on jobbers and

retailers dealing with the boycottee, or dog the steps of mercantile travellers or other possible customers, and "advise" them not to deal with him. The national union, if there be one for that particular trade, instructs its "organisers," "lecturers" and other agents, travelling through the whole country, to give similar warning, and to be vigilant in detecting the articles thus made *taboo*. The "labour" periodicals, and thousands of letters and circulars, skillfully adapted to the purpose, and ranging from open abuse of the victim to charges or doubts as to the quality of his wares, co-operate potently and continuously in the campaign.

What chance has a single employer if more than 2,000,000 individuals, with more than 15,000 committees, are thus actively undermining his business? They are not his personal enemies. They know nothing about him, except that Mr. Gompers has fraternally notified them that he is "unfair." But their warfare is as bitter as if each of them had a personal wrong to avenge. On the other hand, the general public is (or has been hitherto) indifferent to his sufferings, or even regards him as a "grasping capitalist" who ought to suffer, while gentle philanthropists continue to applaud the labour unions as well-meant and mainly good, though now and then they may "make mistakes" which are to be deprecated.

As all business men know, such a battle has often ended in the total ruin and discontinuance of the establishment attacked. But more frequently it has ended in a victory for the Federation, more or less complete. And in such a settlement it has been the practice of the unions from the beginning to make the conquered employer "pay the expenses," aside from his concessions as to wages and other conditions of employment.

I remember well the importation of the boycott from Ireland, and its enthusiastic adoption by labour unions here twenty years ago. At that time a friend of mine was a member of a union in this vicinity. I must add, in justice to him, that he did what he could to keep his union from lawless and foolish measures, and left it when he had failed to do so. From him I learned the notion held by his associates as to the use of the boycott, which they regarded as an irresistible weapon of war. They calculated that, after every victory, "capital" ought to "pay the expenses," so as to put the union treasury in good condition for another fight. Whether this payment was called "wages for waiting-time," or a "fine" or "penalty," or "payment for the benefits of unionisation," as it is called nowadays, makes no difference. It was to be exacted, if that was practicable without total destruction of the business. When, by demanding too much, the union "killed the goose," and so lost the eggs, it had made a "mistake,"—that was all; better luck next time!

Of course, this was blackmail; and I suppose my philanthropic friends still admit that blackmail is naughty. The only point I would make now is that, naughty or not, it has always been a part of the boycott system of our labour unions. Whether a walking delegate, after extorting money on such a pretext, puts it in his own pocket or pays it honourably to his fellow highwaymen, as a good thief should, is a mere question of larceny, and does not concern us here.

Such things are not only done among us; they are done conscientiously, by men who regard the relation between "labour" and "capital" as one of war, justifying the ethics of war. Judge Gray, of the late Anthracite Strike Commission, has fitly characterised this claim. The ethics of war, it must be confessed, are not those of the Golden Rule; but Christianity has at least ameliorated them to this extent, that war can be waged only by sovereign political powers. As Judge Gray says, only the United States of America can declare war here.

But even the ethics of war, permitting deceit, violence, etc., towards a public enemy, which would not be permissible in time of peace, cannot be invoked as justification until after the formal declaration of a state of war. And this

leads us to consider what I may call the boycott of peace.

This ingenious and effective agency involves two main elements:—first, the so-called "union label"; secondly, the "Retail Clerks' Union," which is an active element in Mr. Gompers' conspiracy.

The exact legal value of the "union label" is doubtful. It is not properly a "trade-mark," because it does not signify either the quality or the individual manufacturer of the goods on which it is placed; and the courts have refused at various times to recognise it as entitled to protection. But its commercial value is clear enough. The members of the Retail Clerks' Union throughout the United States are bound to present, and recommend to purchasers, goods bearing this label, while they hold back, as far as possible, competitive goods not bearing it. Of course, an unconscious employer, finding that certain goods sell better than others of the same class, naturally orders them in preference. It is safe to say that this boycott of peace is more effective than the spectacular and dramatic contests in which Mr. Gompers intervenes by general "fraternal" proclamation.

I might enlarge the foregoing statement, but the limits of this article permit only a brief consideration of the essential perils with which we are confronted and the remedies within our reach.

1.—We have among us a strong organisation, or combination of organisations, which distinctly proposes, justifies, and employs illegal means for selfish ends. In cases of disputed equity it constitutes itself both judge and executioner. It assumes a state of war, even without declaring war. It terrorises both "capital" and "labour," and its avowed purpose is to benefit, not the community or workingmen in general, but the members of its own oligarchy. It maintains at State capitals, and at the Federal capital, committees which secure legislation in its favour. It refuses to become, by incorporation, subject to State control. It limits the productiveness of labour and the education of apprentices. It opposes fiercely the system of free and responsible contract between the individual and his employer, or the payment of the individual according to the value of his work. It ostracises and pursues vindictively every workingman who will not become its slave. It discourages every attempt of an employee to rise, by special achievement, above his class. It is the most pernicious embodiment of the spirit of caste which the world has ever seen. And our politicians, theorists, and selfish or sleepy citizens have let it go on in the cool prosecution of its design until it may well fancy itself omnipotent.

2.—To my mind, it is not too late to employ two simple remedies. The first is the fearless enforcement of existing laws. Special State and Federal statutes, it is true, have greatly crippled justice in this respect; but there is enough good law left to protect liberty and order, and such organisations as the American Anti-Boycott Association (which does not assist employers pecuniarily, but simply undertakes to prosecute cases of illegal conspiracy) will be potent agencies in this direction.

The other, and still more important, remedy, is the awakening of public sentiment. If all the men who privately utter their indignation at the brazen claims and acts of "labour" tyrants would publicly speak, and regularly practice, what they believe, this remedy would become at once effectual.

When a boycotted manufacturer can boldly advertise that fact and secure thereby increased custom, the boycott will suddenly die. When a "scab" can readily find employment, according to his real merit as a workman, in defiance of his persecutors,—and all the more readily by reason of their persecution,—this form of the cruelty of man to man will cease, because it will no longer "pay." When a candidate for office who frankly declares his hostility to lawlessness and tyranny, even under the name of "organised labour," can be elected by reason, or in spite of that declaration, politicians will see a great light.

Finally, when those who have derived

from the earlier history of trade unionism the impression that it is a good thing *per se*, shall have realised that union *per se* is only power without moral quality, and that our present labour unions are deliberately using that power for selfish ends through unlawful means, the greatest of all the obstacles to a wholesome uprising of public sentiment will be gone.

In the hope of contributing somewhat to that result the foregoing statement has been written. It does not completely represent the present situation. It does not, for instance, mention the (relatively few) labour organisations which are not "affiliated" with that of Mr. Gompers, and profess different principles.

Nor does it specify those absurd and outrageous freaks of "organised labour," which might be dismissed, perhaps, as occasional "mistakes." But it states what I think to be the greatest present peril of American institutions, and the issue upon which, above all other immediate issues, American citizens ought to unite, in defence of liberty, justice, order and law.

THE ELECTRICAL FIRE HAZARD

By J. C. Forsyth, Chief Inspector for the New York Board of Fire Underwriters

IN this age of wireless telegraphy and wireless telephony we may soon reach the stage of a practical wireless electric lighting and power service; but as it is a "condition and not a theory" which confronts us, we are obliged to deal with matters electrical as they now exist, and not as we may hope to have them in the future.

From the standpoint of the electrician or electrical engineer the marvellously rapid growth of the electrical industry during the last two decades may be interesting, but from the point of view of the individual or corporation who has to carry the fire "risk" and pay the loss, the roseate tints lose their entrancing power, and in a correspondingly increased ratio assume a "fiery red" which it is difficult to contemplate without varied emotions of dread and apprehension.

We are told, and it is undoubtedly true, that electricity is the safest form of artificial illumination and power that is available *if* the prescribed standards are followed and *if* proper maintenance and supervision are given. How those "If's" do loom up to the electrical insurance man who is in a position to know and to appreciate the great chasm between what is, and what should be, and which these "If's" are supposed to bridge!

It is true that standards are constantly being raised and that electrical equipments are being installed in compliance with those higher standards; but the hazard from electrical sources is increasing even more rapidly, and there is a continual overflow, so to speak, which has not been provided against, and which marks the line between perfect safety and danger. When the limit of advancement in electrical science has been reached, when standards are prepared to meet those conditions, and when all electric work is made to conform to such standards, then we may rest contentedly and address ourselves to the simple task of keeping "things in line."

During the year 1902 a total of forty fires was investigated in a certain district and every one of these was unquestionably due to electric wires or apparatus. Thirty of these fires were directly attributable to the breaking down of the insulation on conductors; six were due to overheating of various devices; one resulted from sparks thrown off from a commutator of an electric

motor; one from the ignition of inflammable material by melted fuse metal from a cutout; and two were due to crosses on outside wires which came in contact with miscellaneous conductors entering buildings for different purposes. There were many other fires in the same district during that time which undoubtedly originated from the same source, but owing to the fact that the fires destroyed all evidence of their origin, it was not possible to definitely ascertain the cause.

It will be seen from this record that the protection afforded to these conductors by the material which is at present placed around them in the shape of so called "rubber compound" cannot be depended upon to absolutely protect buildings and their contents from damage due to electricity, owing to the natural deterioration to which they are subject. The dielectric, or insulating compound, becomes dry, hard, and brittle and does not any longer resist abrasion nor prevent moisture from getting to the conductors. A flow of electricity, even if slight, over any such material as rubber, wood, and like substances, during the presence of moisture, carbonises the fibre which thereby becomes a conductor, and if the electricity continues to flow, the material will, sooner or later, burst into flame.

One of the most difficult things an electrical insurance department has to do, is to prove to the lay mind that an installation which has been in use for several years is in unsafe condition owing to the poor condition of the insulation. The claim is made, and perhaps rightly, that the equipment has not given any great amount of trouble, and it is, therefore, difficult to convince the assured of the possibility of fire from electrical causes, as they fail to appreciate the fact that the efforts of the fire department are directed towards the prevention of fires, rather than in determining the cause or origin of a fire after it has occurred.

The old saying that "familiarity breeds contempt" is most applicable to the average electrical equipment when under the supervision of persons who know nothing of the inherent danger of the system. As a rule, no sooner is an equipment completed, than more or less extensive changes and alterations are instituted, these additions and changes being made without any regard whatever to the ordinary precautions which are supposed to be taken in connection with electrical work.

It is a common thing to find on the average equipment, after it has been in service a short time, the panel boards or cut-outs, which, for protection, were encased in cabinets constructed of, or lined with, slate, iron, or similar material, used as storage closets for waste, rags, paper and other combustible things. When the enclosures are too small for this purpose, the doors are either left open or removed, and material of the most combustible nature is stored in direct contact with open fuses, bare bus bars, and switches.

The ease with which an electric light or fan can be installed at any point in a building, or with which changes can be made in the position of a lamp, using for this purpose a flexible cord and connecting it to the most convenient source of supply, is perhaps one of the most common and flagrant violations of prescribed rules. As it requires but a short time, usually, for the insulation on this cord to become abraded, or so dry and hard as to break at any point where it may be disturbed, it can be seen that this condition is likely to result in trouble at any place on the circuit.

The use of large copper wire and extraordinarily heavy fuses in cut-outs, after the fuse originally installed has operated, is on the same order. This can be compared in recklessness only to the tying-down of the safety valve on a steam boiler. A little knowledge of electricity and the laws which govern it in its application to power and lighting systems, well seasoned with ordinary common sense, would enable almost anyone to understand the average precautions necessary in the safe-guarding of electrical wiring and apparatus, and if this knowledge, so seasoned, were only occasionally applied, the fire losses from electrical causes would be largely

diminished. The following simple rules, if followed, would correct a large percentage of defective electrical work:—

Conductors of any description supplying current for electric light or power purposes should not be permitted to come in contact with metal pipes or other conductors.

All fuses should be stamped or marked with the amount of current in ampères which they will carry without melting, and should not be inserted in a circuit protecting a wire having a safe carrying capacity smaller than the fuse. All fuses should be enclosed in fireproof cabinets unless they are of the plug or cartridge type.

Care should be taken to have all "contacts" on circuits, switches, etc., well secured, as a poor contact always results in heat, which in time will ignite any adjacent combustible material.

Current Topics

One of the objections to the erection of electric high-tension wires on poles in cities is the hindrance they offer to free access to a building by means of ladders and fire towers in case of fire. It is at times necessary to cut such wires to afford access to a burning building, — a work which is not highly appreciated by the fire-fighters. Another danger to firemen is that of electric shocks due to currents carried to the nozzle by the stream of water when it comes in contact with live wires. Such shocks have more than once been of sufficient strength to disable firemen for a time, but, so far as is known, no fatalities due to this cause have occurred. In order to ascertain to what extent firemen are subject to risk of life, if at all, when the stream of water thrown from the hose strikes against live wires, a series of experiments were recently undertaken in Germany. They were made with pressures of 6000 volts alternating current, and 550 volts direct current. The stream of water was directed against a portion of the wires from which the insulation had been previously removed. With the 6000 volts pressure it was found that the resistance of about one foot of ordinary hydrant water reduced the potential of the current to a point when it was not dangerous, but the effects were not pleasant. When the resistance of the water was lowered by the addition of a small percentage of soda, the minimum safe length of the stream was increased to about 40 inches. With 550 volts direct current a dangerous voltage was not reached with pure hydrant water, but with the same percentage of soda in the water harmfu

potentials were indicated by the voltmeters used in the tests when the stream of water was only 3 inches long. On the whole the results of the experiments showed that the danger to firemen from the contact of water from the hose with live wires carrying high potentials is not ordinarily so great as has been generally supposed hitherto. This, however, is no reason for lessening the precautions looking to the safety and best interests of all concerned in this matter.

THE price of steel in the United States is now at its lowest point, and there is every indication that from this time on it will become higher and higher, owing to the lack of raw materials. This is the prediction made by Andrew Carnegie last month in an address before the Iron and Steel Institute. Reviewing the progress made in iron and steel metallurgy since 1874, Mr. Carnegie pointed out that in the intervening period the blast furnace product at Pittsburgh increased more than six times, and the rail mill's product about the same. The work of a week is now done in a day; but great as is that contrast, here is one still greater. There have been made and sold without loss hundreds of thousands of tons of 4-inch steel billets at 3 pounds for a penny. Surely the limit has been reached here, and it is doubtful if ever a lower price can be reached for steel. To make that 3 pounds of steel, at least 10 pounds of material were required,—3 pounds of coke, mined and transported 60 miles to the works; 1½ pounds of lime, mined and transported 150 miles, and 4½ pounds of iron stone, mined at Lake Superior, and transported 900 miles to Pittsburgh, being transferred twice, once from cars into the ship, and again from the ship into the railway cars. This was done during the day of depression, when everything was at the lowest. Costs are several dollars per ton higher to-day, during this period of boom in America. The vital question now is where and how a future supply of iron ore can be obtained. The large supplies at the command of the United States Steel Corporation will last them for about sixty years at their present rate of consumption, but sixty years are as nothing in the life of a nation. It is upon future discoveries of iron ore that the future of cheap steel manufacturing, even in America, depends. There are immense deposits in now inaccessible parts. In Utah, for instance, and in Southern California large deposits have been found, so that steel will continue to be manufactured; but it would not be astonishing if its cost were very greatly advanced in the future. It seems almost miraculous that such an article as steel could be produced and sold without loss at 3 pounds for a penny. Mr. Carnegie is convinced that this is a thing of the past

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As an interesting means of publicly demonstrating the principles and some of the possibilities of wireless telegraphy in a popular way, the De Forest Wireless Telegraph Company, of New York, have fitted up and put into service several automobile stations, one of which is shown in the illustration on this page.

A WIRELESS TELEGRAPH AUTOMOBILE STATION

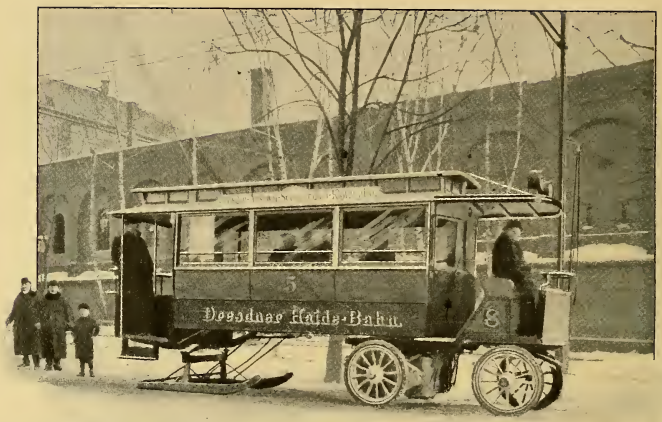
The automobile is run under its own power to the point of review, an operator takes a small "receiver" in his hand to a position with a number of walls and considerable distance intervening between it and the sending station, and the operator at the automobile station turns a switch and flashes a message. Although the apparatus is miniature and utilises but a small amount of power, the spark being audible only a few feet distant, the operator at the receiving point hears, through a head telephone receiver attached to his small instrument, the distinct reproduction of the dots and dashes of the Morse code used at the sending key. Aside from their use for demonstration purposes these automobile stations have been put to practical service in reporting stock transactions in the New York curb market to various brokerage firms, and in sending bulletins from baseball fields to newspaper offices.

VERY large gas engines will be among the most directly interesting features of the power plant exhibit at the St. Louis World's Fair next year. According to particulars supplied by Lieutenant Godfrey L. Carden, R. C. S., of the World's Fair machinery department, the gas engine group will contain, to begin with, the largest gas engine in the world available for service by the spring of 1904. The engine in question will develop 3000 H. P., and will come from the works of the John Cockerill Company, of Seraing, Belgium. It will have a length over all of 67 feet and an extreme breadth to outside of dynamo of 21 feet. The engine will be of the horizontal, two-cylinder type, each cylinder being 51 inches in diameter, with a stroke of 55 inches. The fly-wheel will have a diameter of 26 feet, and when the engine is developing 3000 H. P. the revolutions will number 85 per minute. The extreme length of bed-plate proper will be 77 feet. The dynamo for this engine will probably be furnished by the General Electric Company, of Schenectady, New York. About thirty tons of coal a day will be consumed in the generation of the gas for operating the engine. At the Paris Exposition the Cockerill Company exhibited a 600 H. P. gas engine, and this engine excited more interest and comment probably than any other individual topic in that exposition. The firm of A. Borsig, of Tegel, near Berlin, will contribute a 1750 H. P. Oechelhauser gas engine, and Julius Pintsch, of Berlin, will supply the gas producer for this engine. The total shipment of the Borsig engine and the Pintsch producer will be about 660 tons. The Borsig engine will be direct connected to a Crocker-Wheeler generator, and, at 1750 H. P., will run at a speed of about 100 revolutions per minute. The Pintsch gas producer will be of sufficient capacity to furnish 2400 H. P., and when developing 1750 H. P. the exposition is called upon to give the Pintsch representatives 1575 pounds of anthracite coal per hour, and when not in operation, 50 pounds of coal per hour. The Pintsch producer will supply the engine direct, without any intermediate storage tank. It is proposed to utilise the Borsig engine, in company with three American-built steam engines, to operate the Intramural Railway of the exposition. The Gasmotorenfabrik-Deutz, of Deutz, near Köln, Germany, will contribute to the power plant a 900 H. P. gas engine, and the statement is made by Lieutenant Carden that when he visited the Deutz works recently he was advised by the officials of the company that they have practically completed designs for a 6000 H. P. gas engine. The Allis-Chalmers Company, of Chicago, proposes to install an 1800 H. P. horizontal, two cylinder gas engine of the Augsburg-Nürnberg type. This engine is the design of the Vereinigte Maschinenfabrik Augsburg und Maschinenbaugesellschaft Nürnberg, A. G., of Nürnberg, Germany, the right to build these engines in the United States having been recently acquired by the American firm. The Allis-Chalmers engine will measure 60 feet over all, with an extreme width to outside of dynamo of 19 feet. The fly-wheel will be 16 feet in diameter, and when de-

veloping 1800 H. P. this engine will turn up to 92 revolutions per minute.

In the steam engine line the Allis-Chalmers Company will contribute a 5000 H. P. engine, and this unit will be the largest presentation of power in one steam engine. The foreign offerings in the steam engine line embrace, for the most part, engines of the high-speed variety, and one of the most interesting in this latter group will come from the house of Delaunay-Belleville, Saint-Denis-sur-Seine, France. This engine will develop 1500 H. P., and will comprise a complete unit of engine, boilers and generator. When developing 1500 H. P. the French engine will run at 325 revolutions per minute. This engine is of the vertical, triple-expansion type. Additional foreign offerings embrace a 2500 H. P. vertical, triple-expansion engine direct-connected to a dynamo, the product of Vereinigte Maschinenfabrik Augsburg und Maschinenbaugesellschaft Nürnberg A. G., of Nürnberg, Germany; a 2500 H. P. horizontal, tandem compound engine from Carels Frères, of Gand, Belgium, of the Sulzer type; a similar Sulzer type engine of 2500 H. P. from Franco Tosi, of Legnano, Italy; and a 1000 H. P. tandem engine with direct-connected dynamo from Société Alsacienne de Constructions Mécaniques, of Mulhouse, Germany. The dynamo of the Mulhouse engine will come from the branch house of this establishment located at Belfort, France. Great Britain will send a Willans & Robinson high-speed engine of 1000 H. P. It is further proposed to install one or more briquette making plants, having in view the serving of the boilers with briquette fuel manufactured on the exposition grounds. Briquette machines were secured from William Johnson & Son, Castleton Foundry, Leeds, England, and from one German firm.

As already mentioned, the Borsig gas engine to supply power for the Intramural Railway, will be assisted by three American steam engines. One of these will be a 900 H. P. Corliss type engine running at 85 revolutions per minute, built by the Murray Iron Works, of Burlington, Iowa; the second will be a 750 H. P. modified Corliss engine operating at 100 revolutions per minute, built and exhibited by the Lane & Bodley Company, of Cincinnati, Ohio; and the third will be a 600 H. P. four-valve engine running at 150 revolutions per minute, built and exhibited by the Harrisburg Foundry & Machine Works, of Harrisburg, Pennsylvania. The Crocker-Wheeler Company, of Ampere, New Jersey, will supply the generators for all three of the American-built engines, as well as for the Borsig engine, and in every instance the dynamos will be direct connected to the prime movers and designed to deliver current at 550 volts at the switchboard. As allied to steam engine interests, mention should be made of the steam turbines which will be shown. These will comprise one of 8000 H. P., one of 5000 H. P., and two of 300 H. P. These last two will be of the DeLaval type, one coming from the firm of Greenwood & Batley, Ltd., of Leeds, England, and one from the DeLaval Works, at Stockholm. It is interesting to note that all the engines secured in Europe for service in connection with the power plant, were obtained on a strictly exhibit basis; that is to say, the exposition does not pay anything for the service performed, but the exposition does relieve the exhibitors who contribute engines for work of expenses incident to transportation, installation, maintenance, and insurance. The credit is due to Mr. Thomas M. Moore, the chief of the Machinery Department at St. Louis, for originating the idea that foreign items could be secured to do work while maintaining a strictly exhibit relation to the exposition, and it was under his supervision that Lieutenant Carden scoured the principal manufacturing centres of the Old World in quest of the latest types of engines, boilers, and accessories. The endeavour was also made to secure the latest economical devices and mechanical at-



A GERMAN SNOW AUTOMOBILE OMNIBUS

tachments, and so great was the interest aroused on the Continent and in the United Kingdom that it was eventually found necessary to curtail many of the offerings which were made.

WHAT might properly be termed a snow automobile or a motor sleigh, illustrated on this page, was put to trial last winter by the Allgemeine Elektricitäts-Gesellschaft, of Berlin, the object being to have a species of automobile which might be operated with comparative ease during times of heavy snowfall. To this end the hind pair of wheels of an electric omnibus, of the overhead trolley type which is now becoming common on the roads of Germany and France, was replaced by a pair of sleigh runners, while the driving wheels, in front, were fitted with tires specially designed for taking hold of the slippery surfaces which had to be counted upon. The outfit was purely experimental, and further trials with it are to be made during the coming winter on what is known as the "Haidebahn,"—a trolley omnibus line between Dresden and Klotzsche,—on which electrically-propelled ordinary road vehicles are run for passenger transportation instead of the usual trolley cars running on rails. It does not seem as though a single pair of sleigh runners, as here used, would accomplish much good; in fact, one would imagine that the wheels which they displaced might have been retained with quite as much satisfaction as comes from the runners, though a modified design, with runners both at the front and back of the omnibus and driving wheels midway between, might have better claims to consideration. This, however, remains to be demonstrated. An interesting counterpart to this omnibus is to be found in a so-called snow locomotive which has been in use in the lumber regions of the American Northwest for hauling logs through the woods to a sawmill during the winter. In this locomotive the frames are carried on fore and aft runners; but some of the weight can be shifted on to a so-called traction wheel, or rather drum, made of 1½-inch iron, provided with spike teeth on its surface, and mounted in a special

frame, so that it raises and lowers itself automatically as it moves over uneven surfaces. This drum is driven through gearing, and through it also the steam from the engine is exhausted, thus keeping it hot and enabling it to melt or soften and pack down the snow which it encounters, making a firm surface for at least the sleigh runners behind. The locomotive is understood to have been in satisfactory service for some time, with loads averaging from 30 to 60 tons.

A 2000 KILOWATT transformer, probably the largest ever constructed, was recently completed by the Stanley Electric Manufacturing Company of Pittsfield, Mass., U. S. A., for use in the manufacture of aluminium in the Niagara plant of the Pittsburgh Reduction Company. A heavy current, but one of low voltage, is required in the aluminium reduction process, and accordingly the primary current of 908 ampères and 2200 volts will be transformed in the secondary winding to one of 40,000 ampères at 50 volts. It is this large induced current which makes the machine chiefly remarkable. In point of size, the transformer, as described by the *Scientific American*, is a little over 7 feet square at its base and a little over 8½ feet high. The secondary winding consists of heavy laminated copper bars, and as these must be of large size to carry the enormous current, and cannot, therefore, be bent to form coils in the ordinary sense of the word, they are connected at the top and bottom by heavy copper plates, clamped on. The primary winding of the transformer is made up of copper ribbon coil-sections, a coil-section being placed between each successive pair of bars in the secondary winding. Taps from each coil-section of the primary winding are run up to a switching device, called the "regulator head," by which any number of coils may be cut in or out to change the voltage to any pressure desired, the ratio between the primary and secondary voltages being, of course, directly proportional to the number of turns in each. The iron core consists of thin sheets of soft iron built up about the coils. The upper part of the apparatus, after the core is in position, is surrounded by a coil of piping through which cold water is circulated to carry off the heat generated by hysteresis and by the current in overcoming the resistance of the conductors. An additional coil is placed above the primary winding and within the secondary winding. The entire apparatus is incased in a tank filled with oil which circulates through the transformer and carries the heat from the lower heated sections to the top, where it is taken up by the cooling coils. The oil also serves as an insulating medium in the gaps between the coil sections and between the coils and the iron core. These parts are also separated from one another by sheets of insulating material. The tank in which the transformer is incased is made of heavy boiler plate, which cannot be torn or broken in the event of fire and thereby cause injury to the coils by the release of the oil.

DWELLING houses and factory buildings with concrete walls, in which the concrete has been moulded in place in large masses, have become comparatively common; but in recent years a species of hollow concrete block construction has been introduced, which, in some respects, appears to promise even greater advantages. Such hollow concrete block houses are, in a measure, highly developed examples of the remarkably durable adobe houses of Mexico and the Southwest of the United States, which, though built simply of large sun-dried blocks of clay, appear as though hewn out of one solid mass, and have been found to successfully resist both great heat and heavy tropical rains. Walls built of hollow concrete blocks, with their enclosed air spaces, tend to keep houses warm in winter and cool in summer, and the only problem of satisfactorily building them has been that of cost. This, however, we are told, has now been solved by a machine which turns them out quickly and

cheaply and in all desired sizes. The moulds are made with removable sides, and after the block of concrete has been formed, these sides are swung out of the way and the block can be lifted out and left to thoroughly set. Grooves and tongues can easily be formed in the blocks, enabling them to be rigidly tied together in building up a wall, and openings can also be provided in them to receive the ends of floor beams, the joints being subsequently filled with cement, if desired, to insure greater security. Many houses have of late been built with such blocks, and their popularity seems to be on the increase. In appearance such concrete block walls resemble masonry; in fact, the blocks can be fashioned after almost any desired pattern.

THE NAVY'S NEW ENGINEER-IN-CHIEF

A BIOGRAPHICAL SKETCH OF REAR-ADMIRAL C. W. RAE, U. S. N.

By John C. Kafer

Mr. Kafer was instructor in engineering at the United States Naval Academy at Annapolis for eleven years, during which time Rear-Admiral Rae was there as a student and afterwards as his associate. Mr. Kafer thus was closely identified with the subject of this sketch during his naval career, and is well qualified to speak of him.—THE EDITOR.

IN planning all his campaigns Emperor Napoleon I. is said to have ever kept in mind the principle that France would never be without marshals capable of commanding great armies. It was his belief that a leader would be found available for the performance of every important work, but that no two men would go about the accomplishment of any undertaking in exactly the same manner.

By the recent retirement of Admiral Melville there passed from the United States Navy Department a strong and unique character. It was reserved for him to assume an administrative position at the Navy Department at a time when there was strife within the Navy. In fact, things had reached such a state that it might have appeared to an outsider as if the Line and Engineer Officers of the Navy were more bent upon showing up the weaknesses of one another than in preparing their ships for meeting a common enemy. For twelve of the sixteen years that he held office Admiral Melville was compelled to carry on a strenuous contest for engineering recognition or advancement in the Navy, and yet at all times he was so efficient in the performance of duty, loyal to superiors, rugged in his integrity, and successful in his work that when he surrendered his office to his successor he left the Department with the high esteem and good wishes of all his Line confrères.

Admiral Melville was called upon for a special work, and he did it well. Whatever else resulted from amalgamation of the Line and Engineer Officers of the Navy, there is no doubt that it ended the internal strife that had existed for forty years. It required an heroic remedy to remove this cancer of bitterness, and possibly only a man of Melville's character and determination would have cut as deeply and ruthlessly as he did at the traditions and organisation of the Navy. When even more than his substantial demands had been granted, and the Assistant Secretary of the Navy at that time had officially stated, in submitting the report of the Personnel Board, that the naval officer of the future would become a fighting engineer, Melville could well believe that he had done the work that had

been assigned him, and that he could honourably take the rest which came after forty years of severe and strenuous service.

In looking for a new engineer-in-chief, both Secretary of the Navy Moody and President Roosevelt realised that by reason of the age retirement of Admiral Melville and the special demands of the future, a man of different temperament and training would be required to grapple with the new problems. The remarkable power of Admiral Melville, however, to meet new conditions had been manifested in many instances, and it was probably because the executive authorities were loth to establish the principle of calling upon officers of the retired list for administrative posts at the Department that he was not continued in office. No one knew better than the late engineer-in-chief himself that with the enactment of the personnel law old things had passed away, and that with the advent of a new organisation there would come new methods, as well as decided changes in administrative organisation.

It was no surprise to the naval service that Admiral Rae was chosen as Melville's successor; indeed, his appointment was probably anticipated by three-fourths of the officers doing engineering duty, and by practically all the bureau chiefs at the Department. Just before the retirement of Secretary Long from office that distinguished cabinet officer had asserted that the question of the appointment of an engineer-in-chief had been given serious consideration, and that the appointment of Captain Rae was more than probable.

The new engineer-in-chief of the Navy was born in Hartford, Conn., on June 30, 1847. His father, the Rev. Luzern Rae, took an exceptional interest in the educational training of the boy, and thus he was prepared comparatively young to enter Rensselaer Polytechnic Institute, at Troy, N. Y., a school which, at the close of the Civil War, was probably the most advanced technological institution of the country. Forty years ago Hartford was a great educational centre, and the mental training and discipline that were given the youth under instruction at the various academies and preparatory schools of that city have probably never been surpassed. The early education and training of Admiral Rae were, therefore, in other than a scientific direction, and it was because he possessed natural executive ability and constructive engineering talent that these inclinations overcame his classic environments.

The excellent preparatory education that he received, combined with his aptitude for technical studies and engineering work, permitted him to secure a good standing in his class with comparative ease, and thus he graduated with the degree of civil engineer from the school at Troy when nineteen years of age. In October, 1866, he was appointed an acting third assistant engineer in the Navy, and was assigned to the United States Naval Academy in the newly formed class of engineer students, graduating with the diploma of that institution on June 2, 1868. This class at Annapolis was selected from the graduates of various colleges in the country, and was an exceptionally brilliant set of young men.

In 1870 he was assigned to duty in connection with the Tehuantepec and Nicaragua Canal surveying expedition, being placed in charge of the line of levels in the field and resultant work in the office. The professional training that he had received at Troy particularly qualified him for this duty. As a result of his experience on this surveying expedition, and by reason of his subsequent study of the interocean canal question, he is exceptionally well informed on the subject, and, therefore, his opinion upon this question will be accorded much weight at the Navy Department.

In January, 1874, he commenced his first tour of duty at the Naval Academy, and remained there until 1878, this extended detail of shore duty being due to his special aptitude for imparting instruction and to the high value placed upon his official service by the superintendent of the Academy. After making a three years' cruise in the Pacific, he

was ordered, in 1881, to duty in the Bureau of Steam Engineering of the Navy Department. It was while he was attached to this bureau during this period of shore duty that the machinery of the *Dolphin*, *Boston*, *Atlanta*, and *Chicago* was designed, and he was thus very closely identified with the rehabilitation of the new navy, at least in relation to the design of the motive machinery.

From 1884 to 1887 he was attached to the flagship of the European Station, and during that cruise he had excellent opportunity, of which he took advantage, to carefully note and observe the character of the dock yards and warships of the British and Continental navies. Upon the completion of that tour of sea duty he was again ordered to Washington, where he served as a member of several important boards, and also did duty in the office of Naval Intelligence. From the Bureau of Naval Intelligence he again went to sea, thus gaining practical experience in charge of modern naval machinery. In 1893 he was ordered to duty at the Naval Academy as head of the Department of Engineering. During that second period of shore duty at the Naval Academy he commenced an extended series of experiments on the action and theory of the screw propeller. He also conducted other important research work and investigation.

While at the Naval Academy on his first tour of duty at that institution he served under the late Rear-Admiral C. R. P. Rodgers, an officer of remarkable attainments and ability. Admiral Rodgers possessed many of the strongest qualities of his distinguished kinsmen, Commodores O. H. and M. C. Perry. In himself he was such an example of culture, courtesy, and kindness that he was undoubtedly the Chesterfield of the Service during that period wherein the transition from the old to the new navy took place. No officer of the old navy better upheld the highest traditions and honoured customs of the age of sail than Admiral Rodgers, and no one connected with the new navy had a clearer realisation of the possibilities of the age of steam and electricity. That distinguished admiral was ever desirous of surrounding himself with young officers who would develop into future leaders, and he predicted a highly successful career for Engineer Rae. It is only necessary to recall the fact that among those whom Admiral Rodgers brought near him were commanders like Dewey, Bridgman, Sampson, and Taylor, and lieutenants of the standing of Mackenzie, Meigs, Mason, and Wainwright, to realise his unusual ability to surround himself with growing men.

From the Naval Academy Chief Engineer Rae was ordered, in 1897, to the battleship *Iowa*, the detail being specially pleasing to Captain Sampson, who was then commander of that ship. He served on board the *Iowa* all through the Spanish war, having participated in the bombardment of San Juan and Porto Rico, as well as in numerous bombardments of the forts defending Santiago. He was attached to this ship during the battle of Santiago, and was advanced three numbers in his grade for conspicuous conduct in battle. He was chief engineer of the *Iowa* on her voyage between New York and San Francisco, and while off the coast of South America designed and superintended the repairs to one of her cylinders, a repair which, in character and extent, was one of the largest ever made at sea.

Upon his detachment from the *Iowa* he was ordered to the Newport News shipbuilding establishment as inspector of machinery of the warships building at that place. This work included the inspection of the machinery of the battleships *Kearsarge* and *Kentucky*, as well as the supervision of the detailed preliminary designs of the *Illinois*, *Missouri* and other vessels.

The service of Admiral Rae, both ashore and afloat, has thus comprised duty of a very important, varied nature. As regards personnel, he not only served as an instructor at the Naval Academy, but was executive head of the Department of Naval Architecture and Marine Engineering of that institution. For three years he was a member of the Naval Examining Board. In all prob-

ability he has personally met and studied the capabilities of more commissioned officers of the Navy than any member of the old Engineer Corps now on the active list of the Line of the Navy.

In relation to materiel, he had four years of training and experience in the designing room of the Bureau of Steam Engineering, several years' service as inspector of machinery of warships under construction, fifteen years' sea service as assistant and chief engineer of warships of all descriptions, and three years of duty in the Bureau of Naval Intelligence, which work included the study of the construction, equipment, and organisation of the navies of the world. Supplementing all this varied duty in connection with men and ships have been his research work and original investigation.

His prestige and influence in the Navy are evidenced by the fact that at two annual meetings of the American Society of Naval Engineers he was elected president of that organisation. Upon the formation of the Personnel Board he was made a member of that body, and this was an exceptional official compliment, for probably no board ever appointed by the Secretary of the Navy was more carefully selected. He was also a member of one of the first boards of naval engineers that gave careful consideration to the question of using liquid fuel.

Unusual interest had been manifested in this appointment both by the personnel of the Service and the shipbuilding industry of the country. All within or without the Service who had a personal and direct interest in the work of the Navy fully understood that the character of the appointment would be exceedingly significant, as showing the attitude of both Secretary of the Navy and President of the United States in regard to naval engineering matters.

The appointment of a graduate of the Naval Academy was conclusive evidence that the administrative officials had a high recognition of the worth and efficiency of the engineer officers who had been educated at that institution. There is no doubt that this appointment will lead to still further engineering efficiency at the Naval Academy, since it will act as a spur and incentive for the cadets to specialise in the direction of technical duties.

The selection of Admiral Rae was strikingly suggestive because it showed that President Roosevelt was determined to give a very strict interpretation of that section of the Revised Statutes which provides that the engineer-in-chief of the navy shall be a skillful engineer. The appointment was a distinct encouragement to young officers to specialise in engineering matters, although in no manner could it be construed as a step to the formation of a new engineer corps, since it is well known that Admiral Rae believes that marked success has followed the passage of the personnel bill. There is no doubt that he will earnestly strive to have more officers detailed for engineering duties, though this inadequacy in the complement of officers doing duty beneath the protective deck ought best to be ascribed to the small number of officers in the Service available for any kind of duty.

Probably the most striking feature of the appointment is a declaration of the attitude of the Navy Department upon the question as to whether there should be a consolidation of various bureaus. For several years previous to the retirement of Admiral Melville rumours were in circulation that upon his going out of office there would be a reorganisation of the administrative bureaus. The magnificent manner in which the Navy was prepared for war with Spain is the highest tribute that could be paid to the bureau systems of organisation prevailing at the Navy Department, and the appointment of an officer as engineer-in-chief who will not retire for six years clearly shows the intention of the Secretary of the Navy to continue an administrative organisation which has not only promoted efficiency, but which has insured integrity.

There is no doubt that the personality of Admiral Rae was an important factor in bringing about his appointment. Like his distinguished predecessor, he would command attention in any assemblage. By reason of his military

bearing, courteous manner, personal magnetism, cultured and strong countenance, and kindliness of expression he has commanded the respect and affection of the entire Service. There was not another aspirant for the appointment who did not desire the selection of Admiral Rae if the distinction could not come unto himself. And thus the manner in which Miltiades was honoured could well apply in this appointment, for it was said that when the Athenian generals were asked who was most deserving of honour, there was not one who did not respond that, next to himself, Miltiades had performed the greatest service, and thus it was that he was made commander of the forces and there was a resulting Marathon. There can hardly be found an instance where the selection of anyone for high office who was the second choice of all, and the first choice of the great majority, has ever been regretted.

One of the best proofs of the wisdom of the appointment is the fact that it has resulted in neither heartburnings nor bitter disappointments. There is not an officer doing engineering duty who will not only give the new engineer-in-chief earnest and loyal service, but who does not wish him success in his work. He has already a strong personal following, and this following will increase, for it will be by methods of peace and pacification and by righteous consideration of the claims of others that the sphere of influence of his bureau will be augmented. There will be no yielding to pestiferous beseeching or to continued aggression, and it is certain that there will be no retrogression as to engineering prestige and influence.

The appointment was urged very strongly by Admiral Taylor, Chief of the Bureau of Navigation, and by Admiral Dewey. It is certain that the active personal support of such distinguished officers would not have been given to one who was not qualified in all respects for the important office. Since the return of Admiral Dewey from Manila it is doubtful if he has interested himself in regard to the appointment of any other bureau chief, and the fact that Captain Rae received this cordial and unqualified support is evidence of the esteem in which the new engineer-in-chief is regarded by the Admiral of the Navy.

The question will naturally be asked, —what of the future of the engineer-in-chief of the Navy and his work? It can be expected that he will regard the interests of the Navy and of the country as primary in importance. Then will come the effort to increase engineering prestige and efficiency, but not at the expense of other interests in the Service.

There will be engineering research and scientific investigation, for the problem of the screw propeller, the marine steam turbine, the endurance of boilers, and other important subjects relating to marine engineering will be given special consideration by Admiral Rae.

While the new engineer-in-chief must be appreciative of the distinction of being honoured by appointment as chief of one of the most important bureaus of the Navy Department, there will come the attendant knowledge that the work of the bureau is increasing with each succeeding year, and that by reason of the lack of officers for shore duty there is hardly an adequate complement of officers doing engineering duty at any important naval station. There is no position under the gift of the government that is less a sinecure. Fortunately, however, for the interest of the Service and for his own success, Admiral Rae has a rare capacity for leadership, and his intimate knowledge of officers of the Service will make it possible for him to detail the limited number of experts available so that the best interests of the Service will be safeguarded.

Manufacturing News

A New Painting Machine

THE pneumatic painting machine shown in the illustration on the next page, and made by F. E. Hook, of Hudson, Mich., is an interesitng addition to the line of machinery of this class which has been developed within the past ten or twelve years. For the illustration and particulars we are indebted to the *Scientific American.*

The outfit comprises a self-contained air and liquid pump, fitted with a special expansive plunger, and an eight-inch boiler-tube receptacle in which the liquid and air are compressed. The apparatus thus comprised is mounted upon a substantial platform. Attached beneath the receptacle are two valves, located one above the other at one side of the pump in a special valve-chamber, and playing in removable brass seats and cages. The suction-opening at the under side of this valve-chamber is L-shaped. Into the L thus formed is screwed a piece of one-inch pipe to which the wire-wound suction hose is attached. The suction opening leading into the pumping-cylinder is placed about one and one-half inches above the bottom of the cylinder, and is connected with the lower valve chamber. It is the object of this construction to allow the plunger to close the suction-opening on each down stroke, thereby crowding every drop of liquid or air through the upper valve into the receptacle. From this construction, it follows that the liquid can never come in contact with the packing of the plunger. Indeed, the liquid does not enter the cylinder at all, because on the upper stroke of the cylinder the lower valve is opened and the liquid is drawn through into the lower valve-chamber. The down stroke, whereby the lower valve is closed and the upper valve opened, forces the liquid through the upper valve into the receptacle.

The plunger is so arranged that it can be withdrawn through the top of the cylinder by removing two bolts. Furthermore, it can be instantly expanded without necessitating its removal from the cylinder, simply by disconnecting it from the fulcrum, forcing it into the bottom of the cylinder, and tightening the plunger-rod. The discharge-opening, which is controlled by a special valve, is located at the extreme lower end of the receptacle, the bottom part of which is oval, so that every drop of the liquid is forced out of the receptacle.

Any length of pneumatic air hose can be used; for when the discharge valve is open the hose becomes a part of the

PAINTING A FREIGHT CAR WITH A PNEUMATIC COATING MACHINE MADE BY F. E. HOOK, HUDSON, MICH.

receptacle, increasing its capacity to the extent of the additional volume of the hose. By means of an eight-foot extension rod or tube the liquid can be spread fourteen to sixteen feet overhead without a scaffold or ladder. Within this extension rod is another valve, which gives the operator complete control of the discharge, even though he is working one hundred feet away from the machine. A specially designed nozzle at the end of the extension rod gives to the liquid a whirling motion, so that there is no possibility of clogging the outlet. This special nozzle, in connection with the compressed air, atomizes the liquid so that a fine, filmy mist is formed which penetrates everywhere.

The merits of the construction of the machine are obvious. The pump has simply to compress the liquid and air, and is not used as a means of discharging the liquid. The air, confined above the liquid, forces the liquid out through the discharge-hose and nozzle, so that if the machine is charged with liquid and air, it is not necessary to operate the pump handle in order to empty the receptacle. The chemicals in the liquid cannot reach or destroy the plunger-packing; for they do not pass through the plunger. Since the valves are located at one side of the plunger, they cannot become clogged with sediment. By providing concave seats and giving the valves a rolling motion, each stroke of the handle cleans the valves. The air pumped in while the receptacle is full of liquid passes to the top of the receptacle, thereby stirring or agitating

the liquid constantly. By spreading the liquid into a thin mist through the medium of a special nozzle it is possible to apply a coat more evenly than otherwise and without the streaky appearance given by the brush.

Contrary to the prevalent opinion, the pneumatic coating machine is clean. If the filmy mist falls to the floor, it is hardly noticeable. In painting by brush, huge drops often fall to the floor. The application of the machine is wide, but has found its chief use in warehouses, factories, and for painting large surfaces of any kind, whether they be rough or smooth. In painting rough surfaces the saving in time and labour is particularly marked; for the fine spray permeates every crevice, and the work is far better done than it could be by hand and brush.

Some New Variable Speed Transmission Devices

AMONG the several variable speed transmission devices now on the market the Reeves apparatus, made by the Reeves Pulley Company, of Columbus, Ind., and illustrated in the several accompanying cuts, is worth noting. The device consists of a pair of cones mounted upon both the driving and the driven shafts. They are secured by feather keys, with apexes facing so as to receive the belt which connects the shafts. The cones are adjusted to, and held in, the desired position by the pair of levers as shown in Figs. 1 and 2. The driving and driven shafts are represented, respectively, by *A* and *B*, while *CC* are the previously-mentioned, sphire-mounted cones, forming a *V*-shaped groove for the reception of the belt. The levers *DD*, pivoted between the shafts, carry roller-bearing thrust collars which bear against the hubs of the belt cones. A right and left hand screw shaft, *E*, works these levers simultaneously in opposite directions, and a take-up screw, *F*, serves to give the required tension to the V-shaped driving belt.

In Fig. 1, the cones on the driving shaft *A* are shown separated so as to admit the driving belt to the smallest

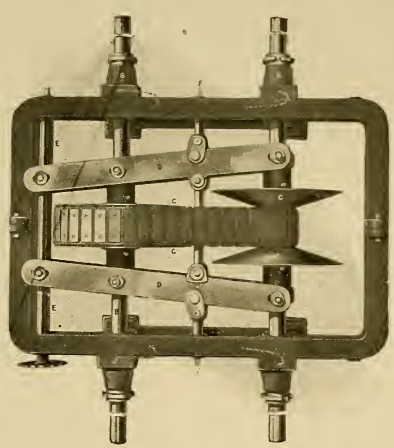


FIG. 1.—THE REEVES VARIABLE SPEED TRANSMISSION DEVICE. MADE BY THE REEVES PULLEY CO., COLUMBUS, IND. DRIVING AT MINIMUM SPEED

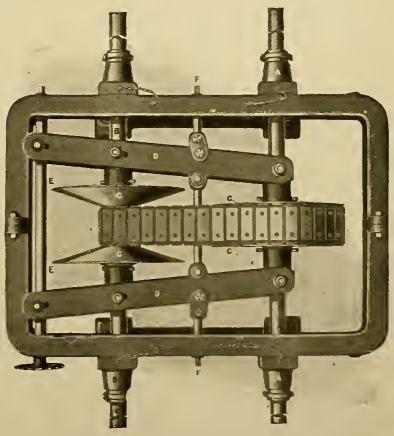
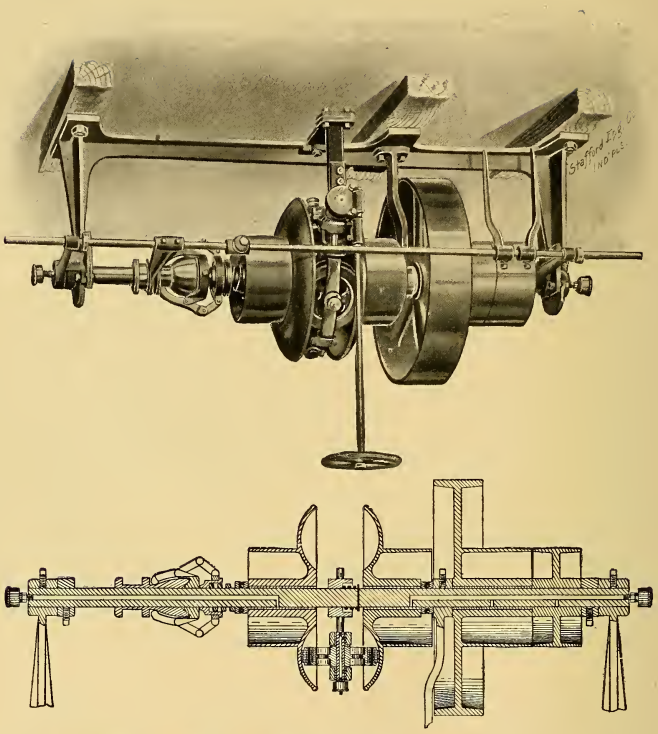


FIG. 2.—DRIVING AT MAXIMUM SPEED



A VARIABLE SPEED PLANER COUNTERSHAFT, MADE BY THE SPEED CHANGING PULLEY CO., INDIANAPOLIS, IND.

driving surface, while the cones on the driven shaft have been brought correspondingly close together, making the belt there assume the greatest driving surface, thus turning the driven shaft *B* at its lowest speed.

In Fig. 2, exactly the opposite conditions are represented, the V-belt on the driving shaft assuming the largest driving surface, and on the driven shaft the smallest surface, thus turning the driven shaft at maximum speed.

The makers turn out thirteen different sizes and seven classes of their machine, each class representing a different range of variation of speed. The range of horse-power transmitted is from 2½ to 150. The maximum change of speed is ten to one. Over three thousand transmissions of this manufacture are said to be satisfactorily operating iron-working tools, cement, paper, canning, centrifugal, biscuit and experimental machinery, printing-presses, embossing machines, testing machinery, and directly connected to constant speed electric motors.

Another speed changing device, designed particularly for a planer countershaft, is shown in the cuts above. It is made by the Speed Changing Pulley Company, of Indianapolis, Ind.

The countershaft is complete within itself and ready to hang. The large or backing pulley runs loose on the shaft, which is held stationary by set screws in the hangers, and is driven by a belt from the line shaft. The forward drive also runs loose on the shaft and is driven by a belt from the line shaft to pulley *A*, which, through the three transmitters, drives pulley *B*. Pulley *B* drives the planer forward.

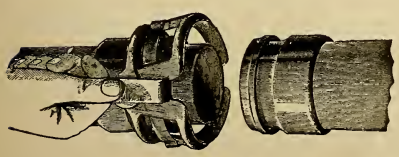
The countershaft is started or stopped by the ordinary shifter, which shifts the belt at one end and compresses or releases the spring at the other end, thereby shifting the belt to or from the loose pulley and making pulley *A* tight or loose.

The hand wheel which is brought within easy reach of the operator changes the speed of the forward drive only. Six turns of the wheel gives a change of speed of 7 to 1. Through the use of this device the speed of a tool may be adjusted to suit different materials. Brass or soft iron may be worked at a higher speed than steel or hard iron.

The company claims that the use of this countershaft will increase the output of the tool by at least 25 per cent.

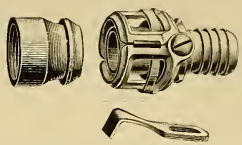
A New Hose Coupling

A NEW hose coupling, applicable alike to compressed air, steam, and water service, has been brought out by the W. J. Clark Company, of Salem, Ohio. It is known as the "Quick as Wink" coupling, and its name is suggestive. The annexed illustrations practically explain how it works.



THE "QUICK AS WINK" HOSE COUPLING. MADE BY THE W. J. CLARK COMPANY, SALEM, OHIO

It is a snap coupling, obviating the use of screws or clamps. A quick thrust connects two lengths of hose with an absolutely water, steam, and air-tight joint, even under high pressures. The connection is positive and can be released only by moving a thumb lever secured to the side of the coupling.



"QUICK AS WINK" HOSE COUPLING, WITH KEY

Another form of the coupling makes use of a key instead of a lever, which is an advantage when the hose is to be dragged about over crowded shop floors.

American Fire Extinguishers for Germany

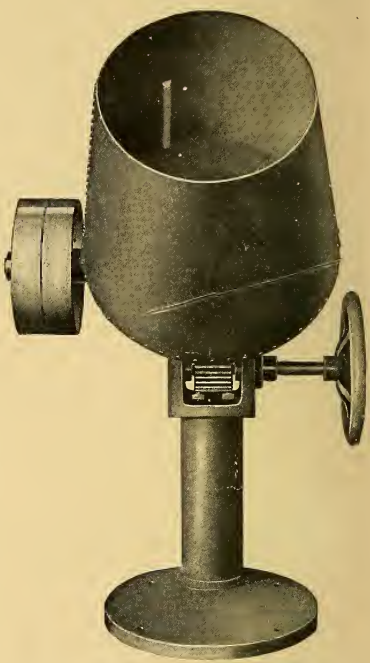
ACCORDING to Consul-General F. H. Mason, at Berlin, fire extinguishers, which are so universally employed in the United States and Great Britain, have, for some reason, been adopted and put into use to a much more limited extent in Germany. As nearly as can be ascertained, only one extinguisher of any importance is made in Germany, and that is said to be of inferior efficiency, and, at the same time, more costly than the best extinguisher made in the United States. The German Postmaster-General has, however, lately given an order for 10,000 such extinguishers, to be used in buildings belonging to that Department. This will certainly give a new and definite impetus to the appreciation and use of fire extinguishers in this country, and it is more than probable that other departments of the government may follow the lead thus taken by the Postmaster-General. These facts are cited to show that this is a favorable time for American makers of fire extinguishers to introduce and push their goods in Germany. Due care should be taken, of course, to protect by patent any special features which are of value; but the spe-

cial advantages of the American manufacturers will be their long experience, the high and fully established efficiency of their appliances, and the cheapness with which they can be manufactured and put on the market. Fire extinguishers which operate by ejecting a fluid are free of duty; those of other constructions are subject to a small duty, not enough to be taken into serious account.

An Improved Tumbling Barrel

THE Globe Machine & Stamping Company, of Cleveland, O., are the makers of the tilting tumbling barrel shown in the annexed illustration. This tumbler will run in any one of several positions, and is adapted to clean, smooth, brighten, or polish sheet metal stampings, small iron or brass castings, forgings, rods, pins, etc., giving, it is claimed, a much finer finish to the work than can be obtained by the use of the ordinary horizontal barrels. The tilting tumblers can be used for either wet or dry tumbling. The work can be seen while it is being tumbled, and samples of the parts in process of finishing may be taken out during operation, without stopping the machine, and the finish inspected as the work progresses. A ratchet and pawl hold the barrel in any desired position, and by means of the hand-wheel the elevation of the barrel may be adjusted to suit the requirements of the parts to be operated upon. Thus the most delicate stampings or castings may be finished without danger of distortion or breakage.

The facility with which the contents of the barrel may be removed when finished, and a fresh lot of parts substituted, makes this style of tumbling barrel a great time-saver.



A TILTING TUMBLING BARREL MADE BY THE GLOBE MACHINE AND STAMPING CO., CLEVELAND, OHIO

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